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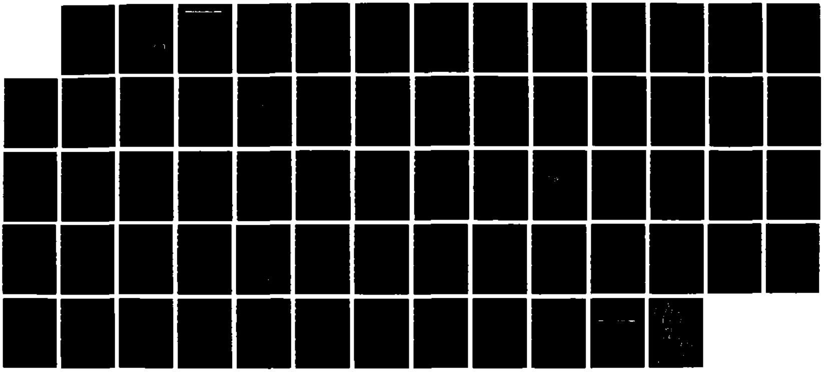

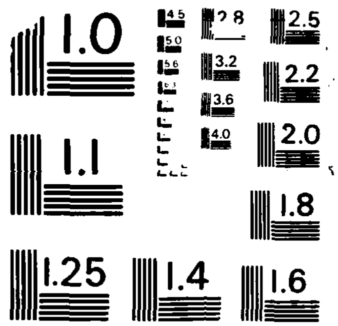

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David Taylor Research Center

Bethesda, MD 20084-5000

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Ship Acoustics Department

Research and Development Report

An Investigation of the Cyclic Nature of the Ambient Noise within Lake Pend Oreille

by

Jonathan Cummings II

DTRC-87/049 An Investigation of the Cyclic Nature of the Ambient Noise within Lake Pend Oreille

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Lake Pend Oreille ambient noise measurements were acquired during 1986 in support of noise experiments conducted at the Navy research facility located at Bayview, Idaho. Noise samples obtained 9 times a day were averaged over hourly, weekly, and monthly periods. Noise trends were summarized. Variations in noise level with times of day and season of the year correlate well with trends in weather patterns and recreational boating use. Daily averaged data clearly show the contribution of recreational boating to lake noise - as much as 10-15 dB average level increase for midday as compared to night. Weekly averages for weekend days are modestly higher (up to 5 dB) than mid-week days, again due to increased weekend use of the lake by recreational boating. Average seasonal trends are generally higher (up to 10 dB) during the summer months than in the winter months.

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ABSTRACT

Lake Pend Oreille ambient noise measurements were acquired during 1986 in support of noise experiments conducted at the Navy research facility located at Bayview, Idaho. Noise samples obtained 9 times a day were averaged over hourly, weekly, and monthly periods. Noise trends were summarized. Variations in noise level with times of day and season of the year correlate well with trends in weather patterns and recreational boating use. Daily averaged data clearly show the contribution of recreational boating to lake noise - as much as 10-15 dB average level increase for midday as compared to night. Weekly averages for weekend days are modestly higher (up to 5 dB) than mid-week days, again due to increased weekend use of the lake by recreational boating. Average seasonal trends are generally higher up (to 10 dB) during the summer months than in the winter months.

ADMINISTRATIVE INFORMATION

This work was performed by the David Taylor Research Center, Ship Acoustics Department (Code 19) for Naval Sea Systems Command (NAVSEA Code 55N) in support of the NAVSEA 6.2 Program, Work Unit 1940-201. Field data were collected starting late in 1985 and are currently ongoing. Data reduction and summaries for the calendar year 1986 were compiled in January 1987.

INTRODUCTION

The David Taylor Research Center's Acoustic Research Detachment at Bayview, Idaho, has been making hydroacoustic measurements within the adjacent lake Pend Oreille for the past 30 years (Fig. 1 and a report by Intolubbe[1] locate and describe the facility). Over those three decades numerous topics in acoustics have been studied ranging from such basic concerns as the physics of freshwater sound propagation and the effects of underwater currents on generated noise to more applied topics like self- and radiated-noise of buoyant vehicles, etc.

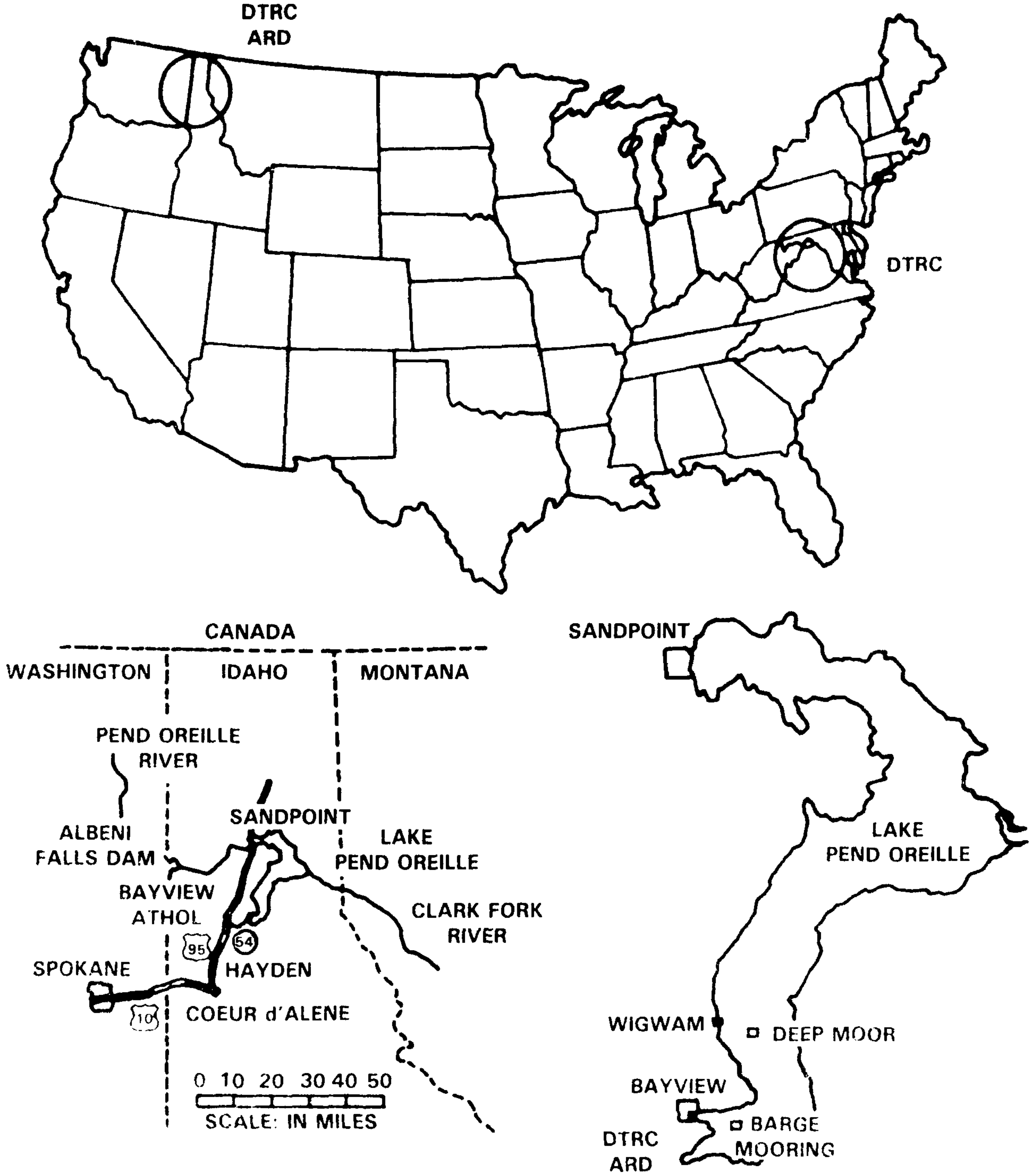

Fig. 1. Location of Lake Pend Oreille.

borne acoustics, target strength, and transmission studies. Some experiments have been independent of the lake ambient acoustic background noise, but most of the tests have required the lake noise background to be well below the phenomena being measured. The goal of this study is to determine the cyclic nature of the ambient noise background in Lake Pend Oreille during the 1986 calendar year and to quantify the contribution of recreational boating to the average lake ambient noise. The approach taken was to measure the broadband noise at the deep moor test location of Lake Pend Oreille at repeated daily intervals (nine times a day) for the 365 days of 1986. Events, average noise levels, and standard deviations in ambient noise for daily hours, days of the week, and months were computed from the acquired data base and cyclic trends were determined.

BACKGROUND

Ambient hydroacoustics of ocean environments have been well studied for the past 40 years. In the 1940's, Knudsen[2] pioneered studies of ocean ambients by quantifying the relationship between wind speed and underwater noise. The sea state curves derived from Knudsen's measurements are still a widely used and accepted standard in ocean acoustics. Marsh,[3] Wenz,[4] and others further studied the effects of wind and wave height on generated underwater ocean noise. Marsh improved Knudsen's low frequency noise estimates by identifying turbulent pressure fluctuations as controlling the 1- to 100-Hz spectra. He also showed that oceanic boat traffic dominates the midfrequencies (10 to 1000 Hz) of an ocean ambient noise signature.

In-depth studies by Franz[5] in the 1950's investigated mechanisms responsible for generating underwater noise, particularly the effects of precipitation.

Franz developed an empirical relation between rain rate, drop size, and entry angle and the resulting underwater noise. Recent work by Scrimger[6] and Scrimger et al.[7] characterized the high frequency ambient spectra caused by precipitation. Scrimger's ambient signatures were obtained from a fresh water lake (Cowichan Lake, British Columbia, Canada) and should compare better with the signatures cited in this report than those derived from an ocean environment.

Work by Arase and Arase[8] and Dyer[9] was concerned with investigating the statistical nature of ocean ambients. These and other authors have reported the Gaussian-like structure of the distribution of ambient noise levels. Penhallow and Dietz[10] were successful in distinguishing the ambient noise dependency on wind and wave height. They found the measured underwater noise to be more dependent on wave height than on wind speed for steady wind conditions, and more dependent on wind velocity than on wave height under transient wind conditions.

This report documents and discusses the long term trends of ambient noise in a recreational lake over the course of one year.

DISCUSSION

GENERAL

A description of the ambient measurement system is given in Appendix A. Unless otherwise noted, average sound pressures cited throughout this report are one-third-octave band levels at band 30 (1-kHz center band frequency) and given in dB referenced to 1 μPa. Nine samples of the lake ambient noise were taken per day at intervals of 2 hours during the day and 4 hours at night. The increased daytime sampling was needed to better define times of higher ambients. Monthly and weekly averages are compiled using six daily readings (0200, 0600, 1000, 1400, 1800, and 2200 hours). This 4-hour sampling period provides even weighting of day-to-night.

CHARACTERIZING THE AMBIENT NOISE SPECTRUM

Generally, the 2014 one-third-octave noise signatures acquired from the 1986 ambient data base had spectral characteristics similar to ideal Knudsen sea state curves. Broadband sound pressure levels ranging from recording system noise floors (50-55 dB re 1 μPa) to levels in excess of 100 dB maintained spectral shapes similar to those of Knudsen sea state curves. With the exception of ambients influenced by rain, the frequency dependence of the spectral noise was sloped slightly negatively from one-third-octave center frequencies of 400 to 20,000 Hz. Rain-influenced ambients displayed a similar negative spectral slope up to 10 kHz but were characterized by a distinctive 10-dB peak in frequencies between 10 and 20 kHz. This "rain peak" agrees with that found and well documented by many others studying ambient noise - see Scrimger.[7] Figures 2-4 provide examples of the 1986 Pend Oreille ambients; Fig. 2 is a quiet or lower ambient, Fig. 3 is a noisy or higher ambient, and Fig. 4 is a medium level ambient measured during a steadily falling rain.

Level changes in two noise signatures that display little frequency dependence may be well approximated by measuring the level changes in a single frequency point between those two signatures. Ideally, two frequency independent signatures (white noise) of different levels will differ by that same level for all frequencies. Figure 5 compares the yearly average of four one-third-octave center frequency bands (0.4, 1, 4, and 10 kHz) and shows that the characteristics of the curves are quite similar. Levels are highest at 0.4 kHz and lowest at 10 kHz because of the shaping of the spectra due to weather. Knudsen sea state curves have a slope of roughly -0.7 dB per one-third-octave band which predicts a 10 dB difference between the 10-kHz and 400-Hz levels for a single spectrum. The spectra for May-December are shaped more like a spectrum predicted by Knudsen

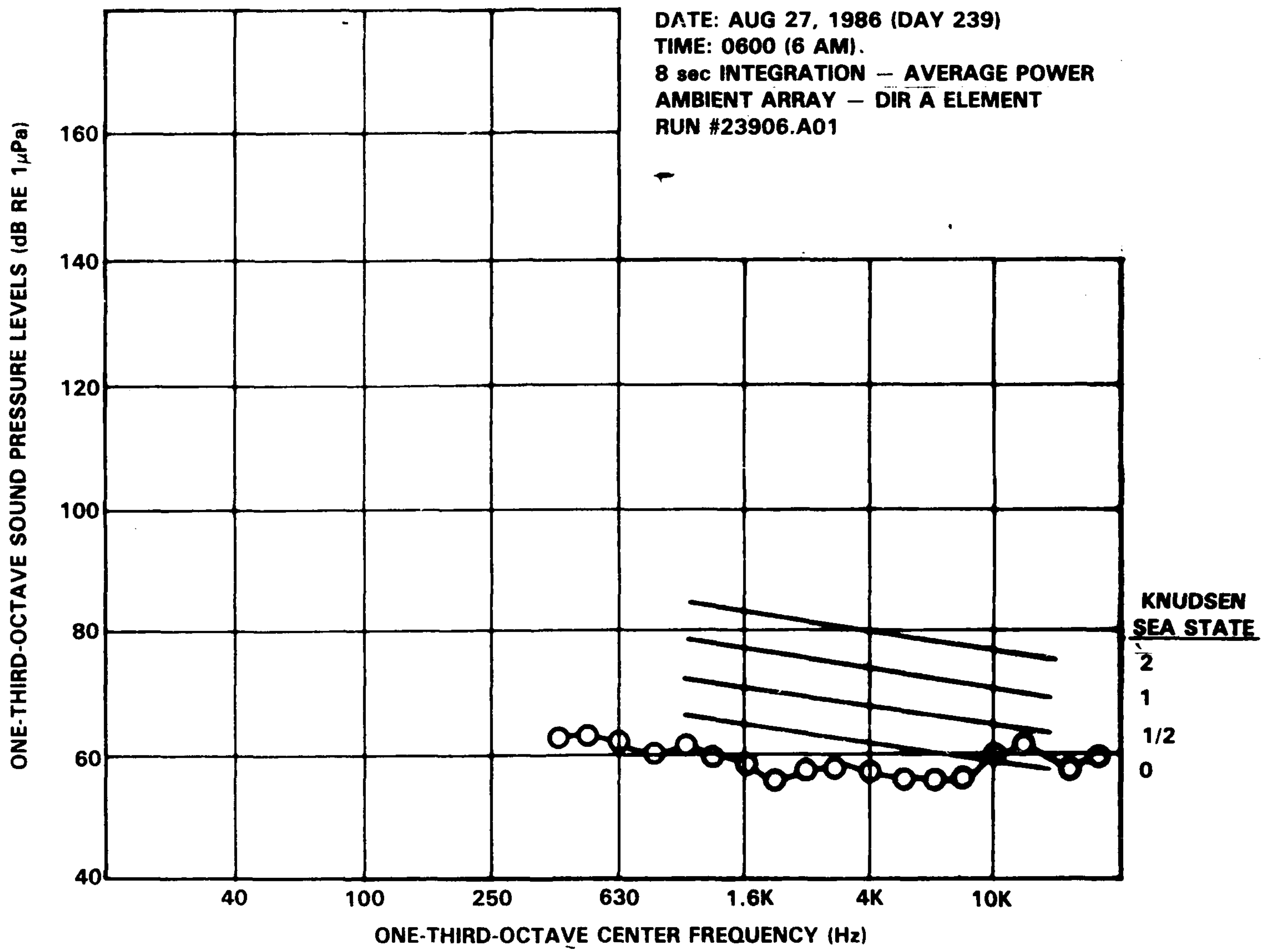

Fig. 2. Example of lower level or quiet 1986 Pend Oreille ambient noise signature.

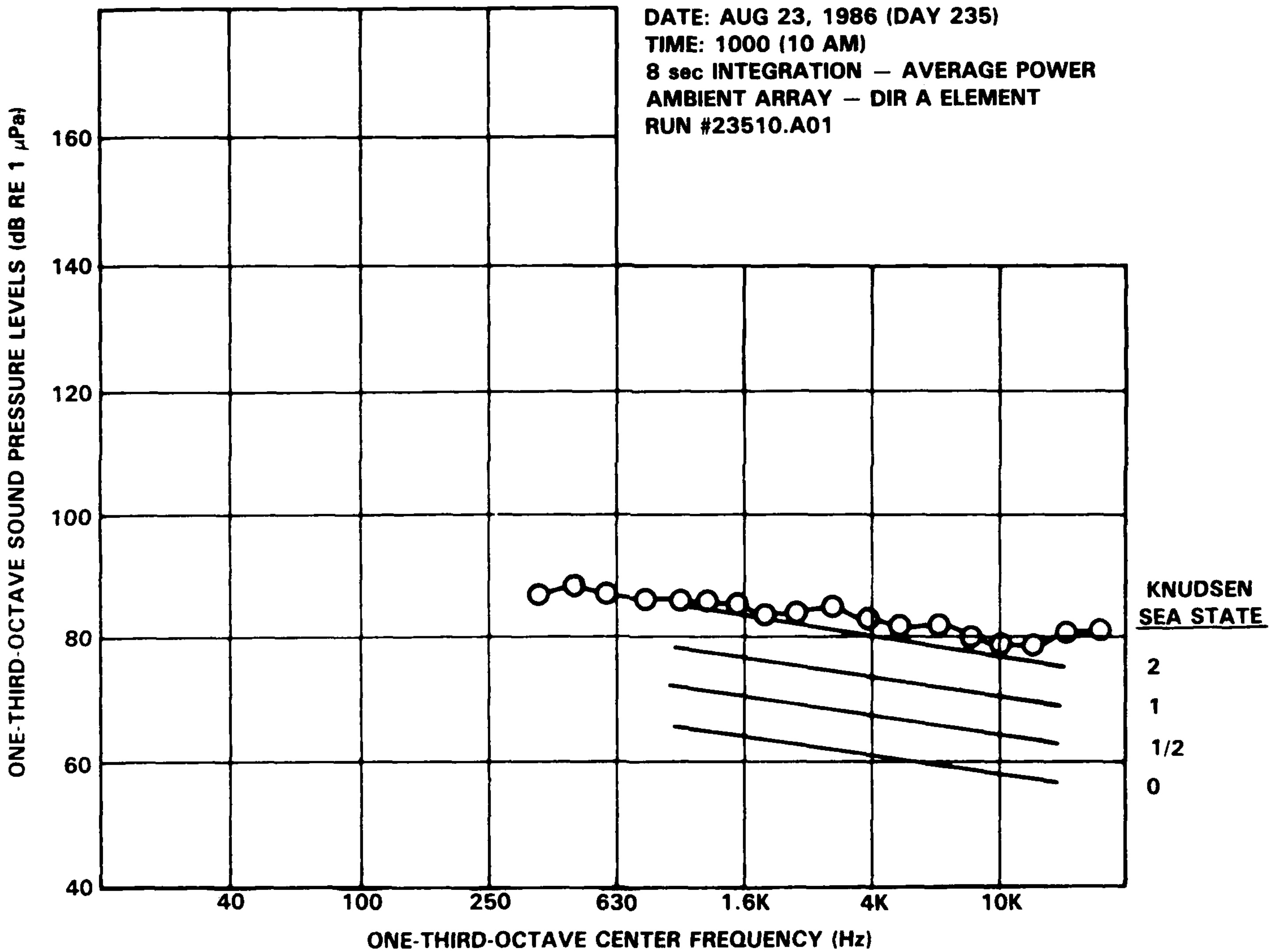

Fig. 3. Example of higher level or noisy 1986 Pend Oreille ambient noise signature.

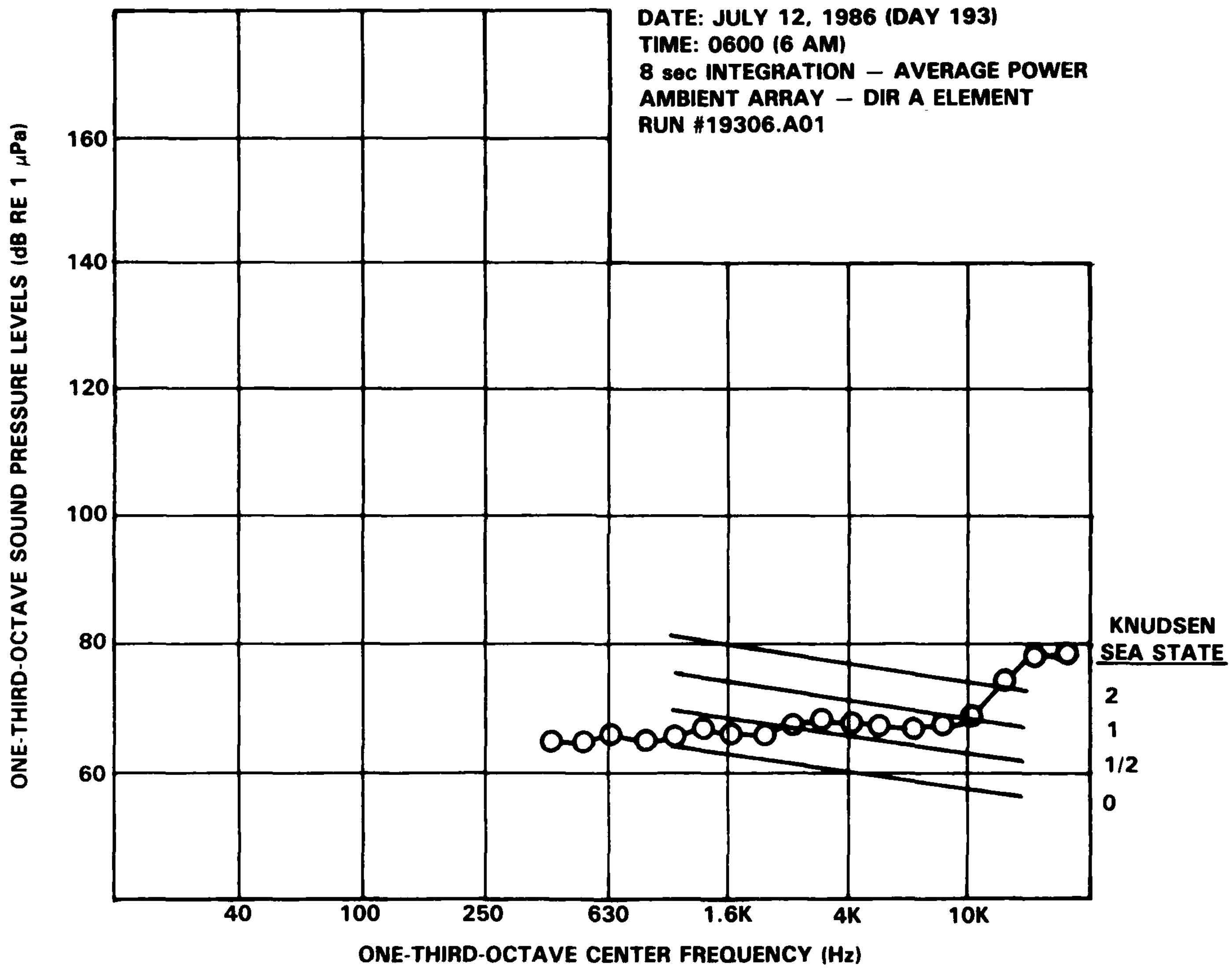

Fig. 4. Example of medium level, rain influenced 1986 Pend Oreille ambient noise signature.

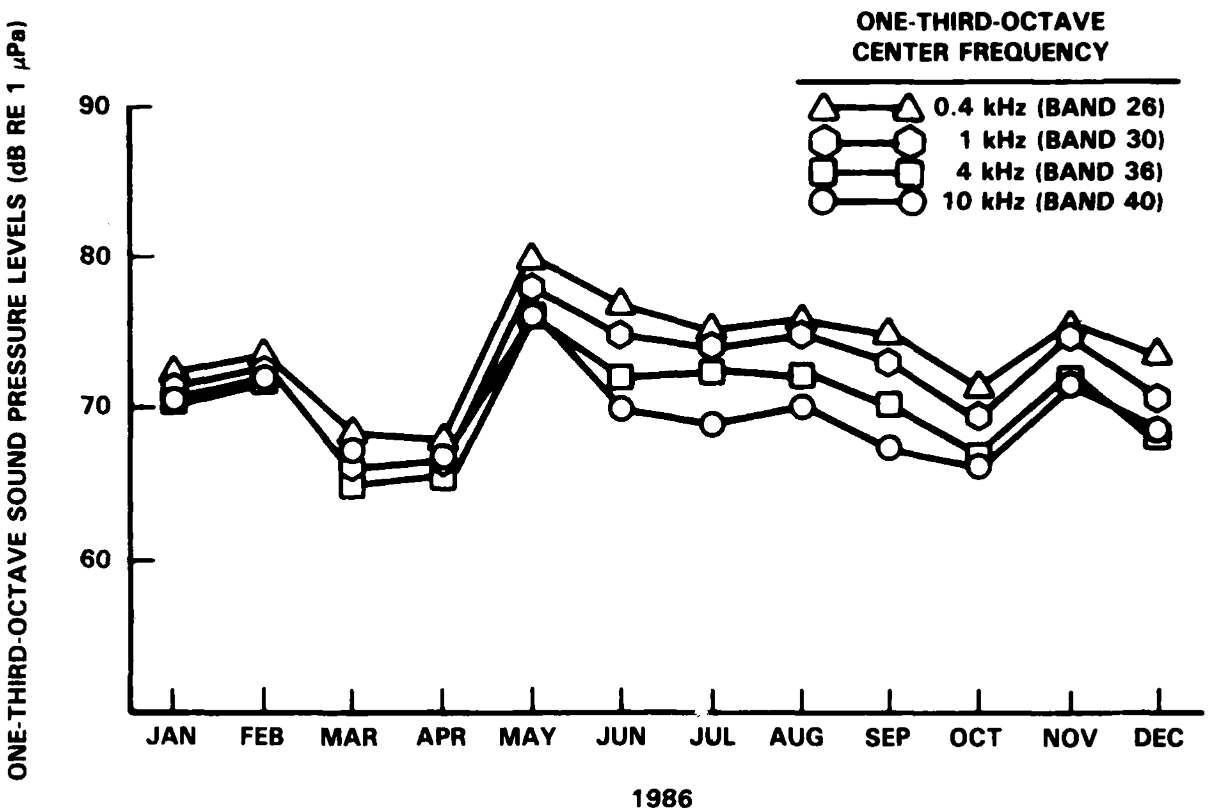

Fig. 5. A comparison of 1986 monthly average Pend Oreille ambient noise levels (average of readings at 0200, 0600, 1000, 1400, 1800, and 2200 hours) for one-third-octave bands 26 (400 Hz), 30 (1000 Hz), 36 (4000 Hz) and 40 (10,000 Hz).

than those for the months of January-April. It is not clearly understood why the average levels for January-April are flatter than averages for the other months, although it is likely that this flatness is due to some winter weather-related phenomena. This report summarizes the ambient levels at 1 kHz and assumes that the changes in these levels relate to the changes in the entire spectrum of the ambient levels.

Temperature and velocity gradients within an ocean are known to affect hydroacoustic propagation. Gradients create density layers within a body of water that bend pressure waves and attenuate noise levels, causing acoustic ambients to have a depth dependence. Figure 6 compares average winter and summer temperature profiles within Pend Oreille. Winter water temperatures are approximately a constant 40°F for all lake depths, giving the lake an isovelocity profile (constant sound speed at all depths). Homogeneous velocity profiles propagate sound waves equally in all directions and decrease the potential for depth dependence in an ambient noise measurement at a given station. Summer lake temperature profiles have a high negative temperature (and velocity) gradient near the lake surface. (Most of the change in temperature within the lake occurs within the top 150 ft. From 150 to 1000 ft, the lake is roughly isothermal at about 40°F for all times). According to Snell's Law, negative velocity gradients act to bend acoustic waves downward. This condition should not give lake ambient noise any depth dependence because surface originating noise will be allowed to propagate freely to deeper depths. (Positive gradients overlying negative gradients create surface layers which trap sound energy and reduce propagation to deeper depths.) Figure 7, which compares two ambients taken simultaneously at 500 and 1000 ft, shows that the ambients are quite similar and that there is no significant depth dependency of the ambient noise within Pend Oreille.

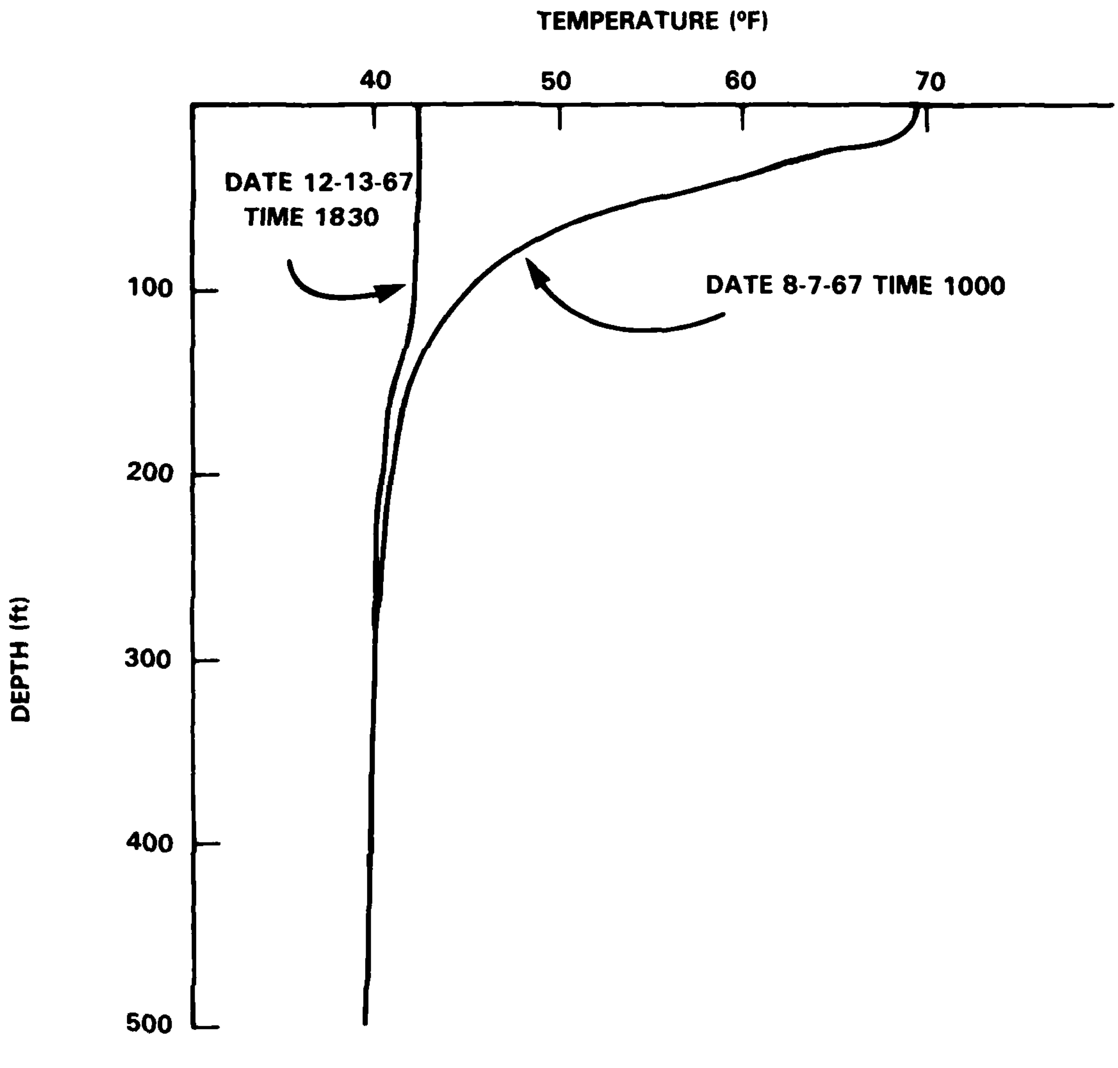

Fig. 6. A comparison of the winter and summer water temperature profiles for Lake Pend Oreille.

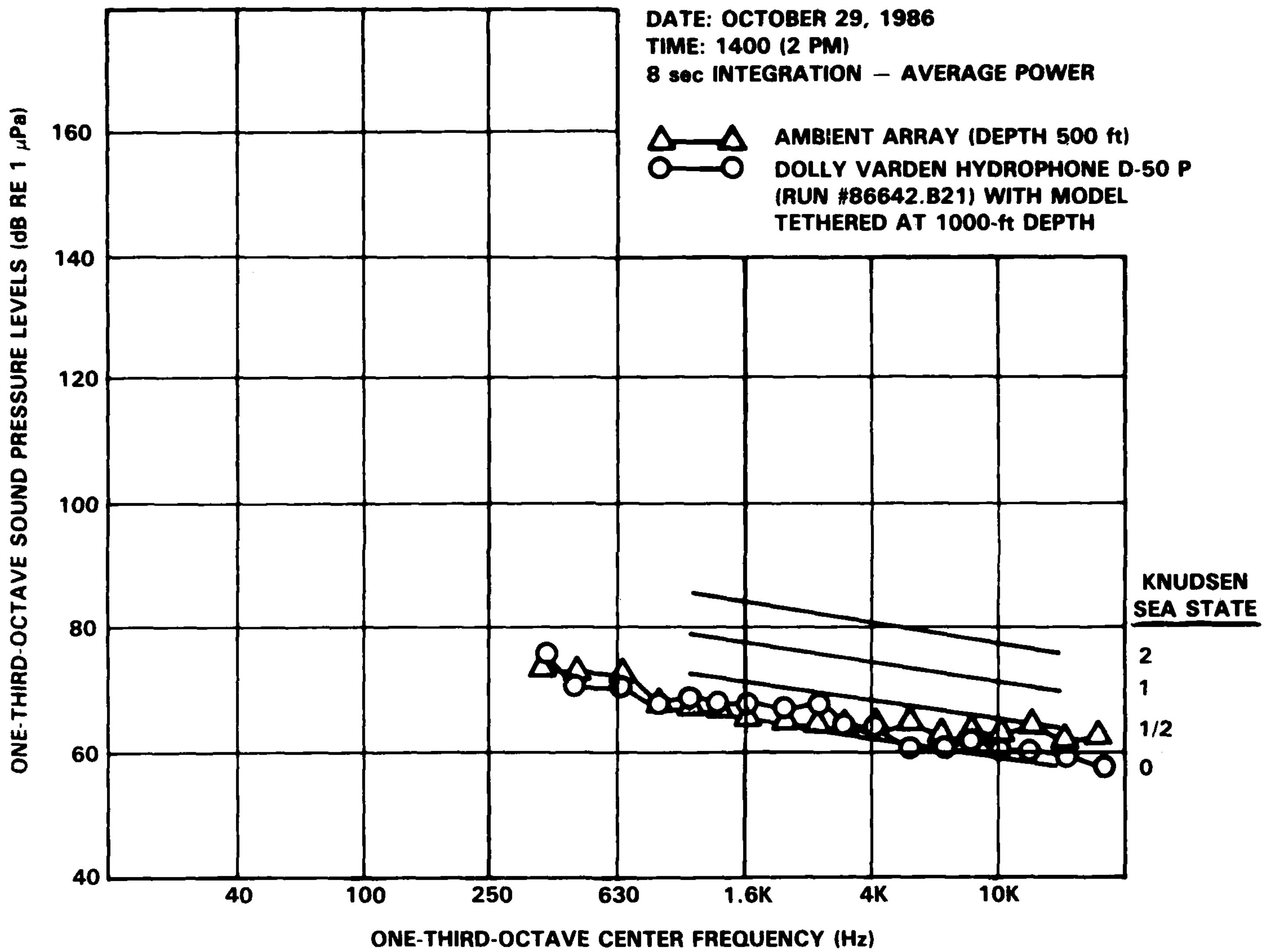

Fig. 7. A comparison of 1986 Pend Oreille ambient noise levels at depths of 500 and 1000 ft.

Bottom and surface reflections, which can affect the ambient spectral characteristics, are reduced on Lake Pend Oreille by the lake topography. The lake is steeply banked and has a maximum depth of 1170 ft; this contour increases dispersion and decrease strong reverberations. The lake bottom is nearly devoid of biologically generated noise and is covered with up to 60 ft of silt which absorbs acoustic energy and reduces reflections. These conditions make the ambient noise levels within the lake more isotropic and lessen the complex acoustic paths associated with typical shallow water environments.

FACTORS CONTRIBUTING TO LAKE PEND OREILLE AMBIENTS

Many factors that control ocean ambients also affect lake ambients. Winds agitate lake surfaces and create waves which crest and break forming momentary collapsing air pockets. This surface turbulence is manifested as broadband noise projected downward. For frequencies between 400 and 20,000 Hz, this projected noise decreases approximately 3 dB/octave, when measured in 1/3-octave bands, and is related directly to wind speed. Noise due to rain depends on rain rate and drop size and, like wind generated noise, is also projected downward. Noise levels between 400 and 8000 Hz due to rain with no wind influence increase uniformly in level with increased rain rate. (Lokken and Bom[11] and more recently Scrimger[7] observed an approximate 4 dB broadband noise increase with each doubling of rain rate.) Noise spectra in the 10- to 20-kHz range due to rain are highly peaked but also increase with increased rain.

Ocean noise spectra between 10 and 1000 Hz are heavily dependent on shipping density and unlike weather phenomena, are projected laterally through the ocean. Distant recreational boating on Lake Pend Oreille (waterski boats, yachts, trollers, etc.) was observed to control the entire measured ambient spectrum (400-20,000 Hz) at quieter weather states.

Low frequency noise due to biologics, which is often observed in the ocean, is noticeably absent from lake noise spectra. Subsurface turbulence and currents that often affect ocean noise signatures at very low frequencies are often reduced or absent in lakes. Thermal excitation on a molecular scale controls very high frequencies in ambient signatures and may ultimately set the lower level limit throughout all frequencies. (High frequency levels are also limited by higher transducer self-noise floors which are limited by current hydrophone crystal design technologies).

Lake Pend Oreille ambients may be generically described as the power summation of the known noise sources; i.e.,

Ambient level = base level + wind noise + precipitation noise
+ boat noise.

The base level is invariant and provides the lower limit of the ambient level. Noise from wind and precipitation varies at random intervals and is ideally distributed in a Gaussian-like manner (global meteorological patterns may account for some natural cycling in weather at particular geographic areas and may act to skew noise distributions). Noise generated from recreational boating is highly concentrated in the summer months and is generally limited to the daylight hours. (Although the lake surface does not freeze, Pend Oreille is nearly devoid of recreational boating during winter months.) Over a large sampling, boat noise contributes little to the average ambient noise levels during winter and nighttime hours.

1986 LAKE PEND OREILL_ AMBIENT NOISE TRENDS

The 1986 Lake Pend Oreille ambient noise levels for one-third-octave band 30 (1 kHz) are listed in Appendix B (zeros within the matrix indicate that no readings were taken). A composite histogram for the 2014 day-biased readings and the 1328 even weighted, 4-hour interval readings taken in 1986 are shown in Fig. 8. Histograms of the monthly levels distribution are presented in Appendix C. These data show that, although the yearly ambient levels is distributed in a Gaussian-like manner, the distribution of the individual months is less so. Fall months display a more Gaussian-like distribution than winter months but less than those of summer.

Daily Trends

A composite summary of the 1986 levels is presented in Table 1. The yearly and seasonal averages of the daily cycle are presented in Table 2. The yearly average is plotted in Fig. 9. The daily curve is smooth with levels ranging from about 65 to 78 dB; it peaks at 1400 hours and has a minimum at 0200 hours. This midday increase is mostly due to prime time recreational boating on the lake. A seasonal breakdown of the hourly average levels is presented in Fig. 10 and shows these midday trends better. The summer midday hours are some 20 dB higher than the summer night levels while the winter midday levels are only about 7 dB higher than the winter night levels. If one concludes that for a long term average the influence of recreational boating is largely absent from any times of the winter spectrum, then the difference in the midday summer and midday winter levels is due mostly to boat noise. This difference is about 13 dB which compares well with the overall yearly average differences between day and night levels and is another estimate of the difference in ambient noise levels in the presence and [illegible]

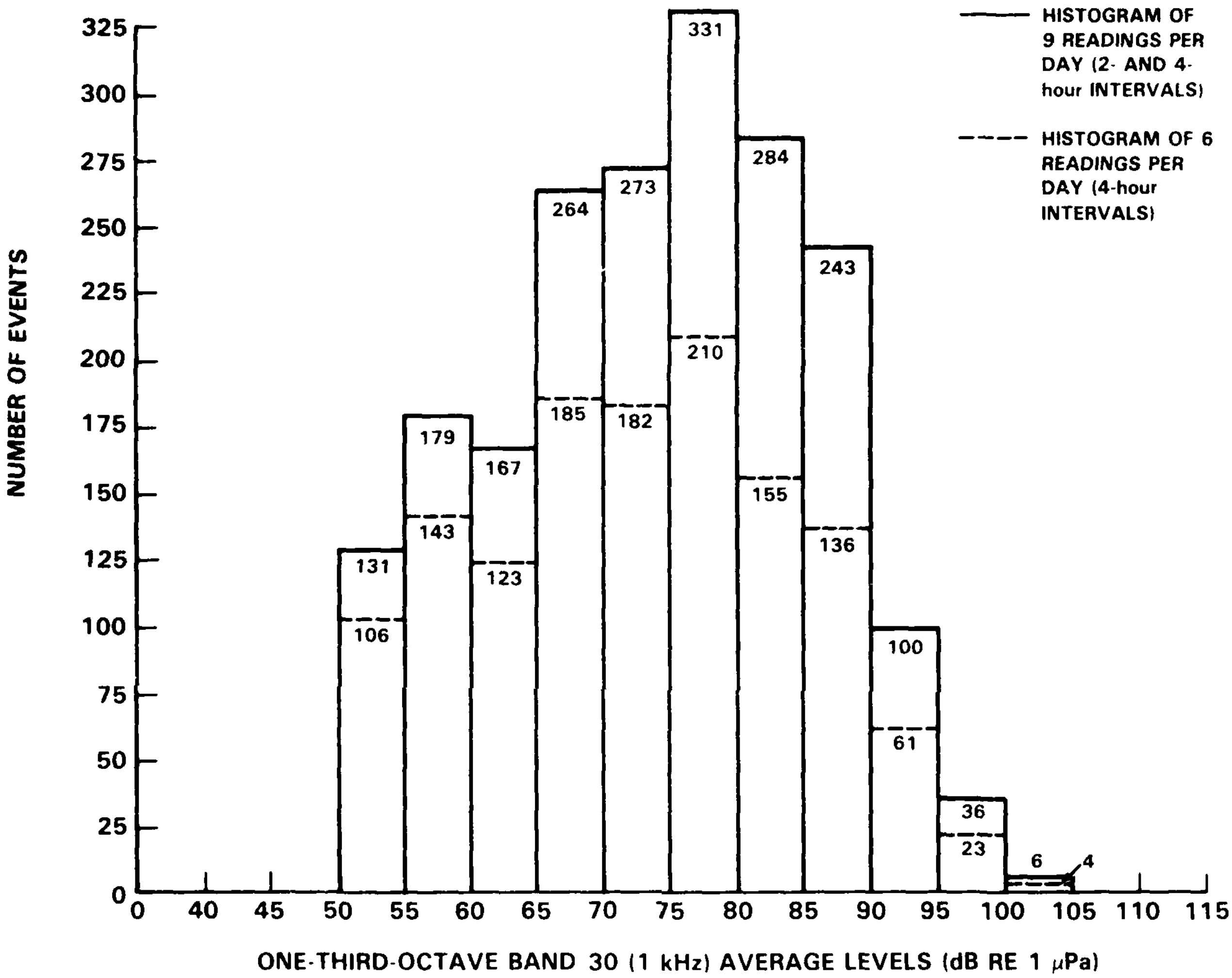

Fig. 8. Histogram of 1986 Lake Pend Oreille data base for 1-kHz, one-third-octave ambient noise levels.

Table 1. A composite summary of the average 1986 1-kHz, one-third-octave band Lake Pend Oreille ambient noise statistics.

HOURS

	0200	0600	0800	1000	1200	1400	1600	1800	2200
JAN	75.1	74.8	74.5	75.5	68.3	69.1	65.0	63.9	69.3
FEB	73.1	74.1	73.6	73.3	73.8	75.3	71.9	68.4	69.9
MAR	59.8	63.0	69.0	69.6	74.2	74.5	72.6	66.1	61.4
APR	61.0	65.3	71.4	73.0	70.1	74.5	65.5	63.2	65.6
MAY	0.0	79.0	75.3	0.0	84.6	82.7	79.2	84.5	63.2
JUN	61.9	75.5	72.3	80.6	82.2	82.5	81.5	80.4	68.7
JUL	63.3	72.1	75.6	73.6	83.4	85.1	81.0	82.3	72.4
AUG	61.5	68.8	76.9	79.3	84.8	87.9	85.7	86.9	71.8
SEP	67.1	68.7	76.7	80.5	81.1	82.6	77.1	71.7	66.7
OCT	61.6	67.9	76.3	74.5	74.9	75.4	73.4	73.5	61.9
NOV	73.3	72.8	82.6	75.3	80.6	78.6	81.3	73.8	72.9
DEC	70.0	71.1	70.9	70.5	69.6	72.6	69.7	69.0	68.7

DAY 1 THRU 365

	0200	0600	0800	1000	1200	1400	1600	1800	2200
EVENTS	205	214	222	238	237	227	228	220	224
AVERAGE	65.5	70.5	74.5	74.8	77.5	78.3	76.1	73.6	68.4
STD DEV	11.3	10.3	10.3	10.7	10.3	10.4	11.0	12.4	10.4

WEEK 1 THRU 52 (4-hour INTERVAL AVERAGES)

	SUN	MON	TUE	WED	THU	FRI	SAT
EVENTS	188	176	186	198	190	198	198
AVERAGE	72.1	71.9	71.2	70.8	71.1	73.9	73.2
STD DEV	13.1	11.4	10.7	11.0	11.4	11.9	11.9

MONTH 1 THRU 12 (4-hour INTERVAL AVERAGES)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
EVENTS	88	118	120	70	16	125	165	170	64	132	95	165
AVERAGE	71.5	72.7	65.9	67.1	78.0	75.1	74.1	75.0	73.4	69.3	74.9	70.4
STD DEV	10.8	12.4	13.3	12.8	10.8	10.0	10.9	12.5	10.3	11.1	10.5	9.5

NOTE: 1 kHz LEVELS (dB RE 1 μPa)

Table 2. A daily summary of the 1986 1-kHz, one-third-octave band Lake Pend Oreille ambient noise statistics.

	0200	0600	0800	1000	1200	1400	1600	1800	2200
COMPOSITE DAY – 1 THRU 365									
EVENTS	205	214	222	238	237	227	228	220	224
AVERAGE	65.3	70.5	74.5	74.8	77.5	78.3	76.1	73.6	68.4
STD DEV	11.3	10.3	10.3	10.7	10.3	10.4	11.0	12.4	10.4
WINTER DAYS (JAN – MAR)									
EVENTS	57	56	56	59	55	56	53	59	39
AVERAGE	69.3	70.5	72.2	72.6	72.6	73.3	70.6	66.3	65.2
STD DEV	13.3	11.8	11.9	11.9	11.8	11.8	12.5	13.0	14.0
SPRING DAYS (APR – JUN)									
EVENTS	32	33	34	31	41	41	37	37	37
AVERAGE	61.6	71.9	72.7	77.9	79.1	80.1	76.8	75.7	67.1
STD DEV	9.5	10.7	9.7	10.0	10.2	8.8	11.3	11.4	9.8
SUMMER DAYS (JUL – SEP)									
EVENTS	71	71	61	71	69	59	63	56	71
AVERAGE	63.0	70.2	76.2	77.1	83.5	85.7	82.5	82.4	71.3
STD DEV	9.5	9.0	7.7	10.1	6.2	7.2	6.8	9.0	7.4
AUTUMN DAYS (OCT – DEC)									
EVENTS	45	54	71	77	73	71	75	68	77
AVERAGE	66.7	69.9	75.7	73.1	74.6	75.2	74.3	71.6	67.8
STD DEV	11.1	10.3	10.9	9.9	9.5	8.6	10.1	10.3	10.6

NOTE: AVERAGE ONE-THIRD-OCTAVE BAND 30 (1 kHz) LEVELS (dB RE 1 μPa).

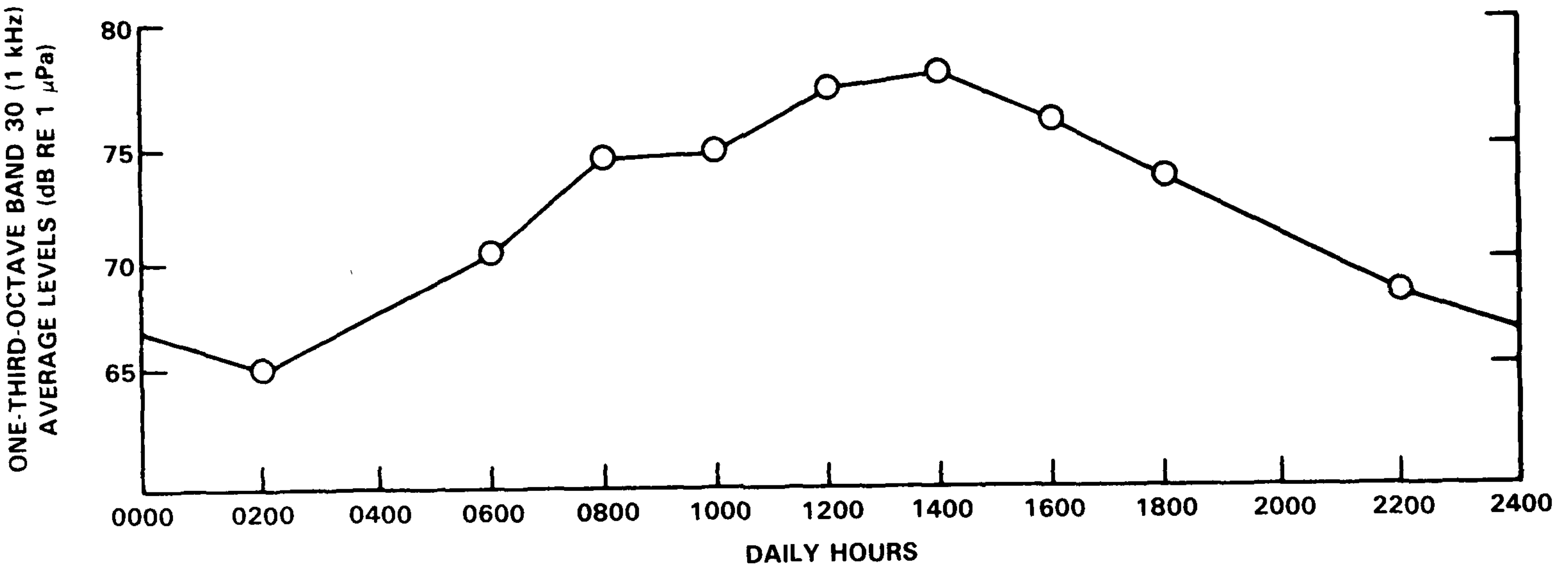

Fig. 9. Hourly 1986 average ambient noise levels for one-third-octave band 30 (1 kHz).

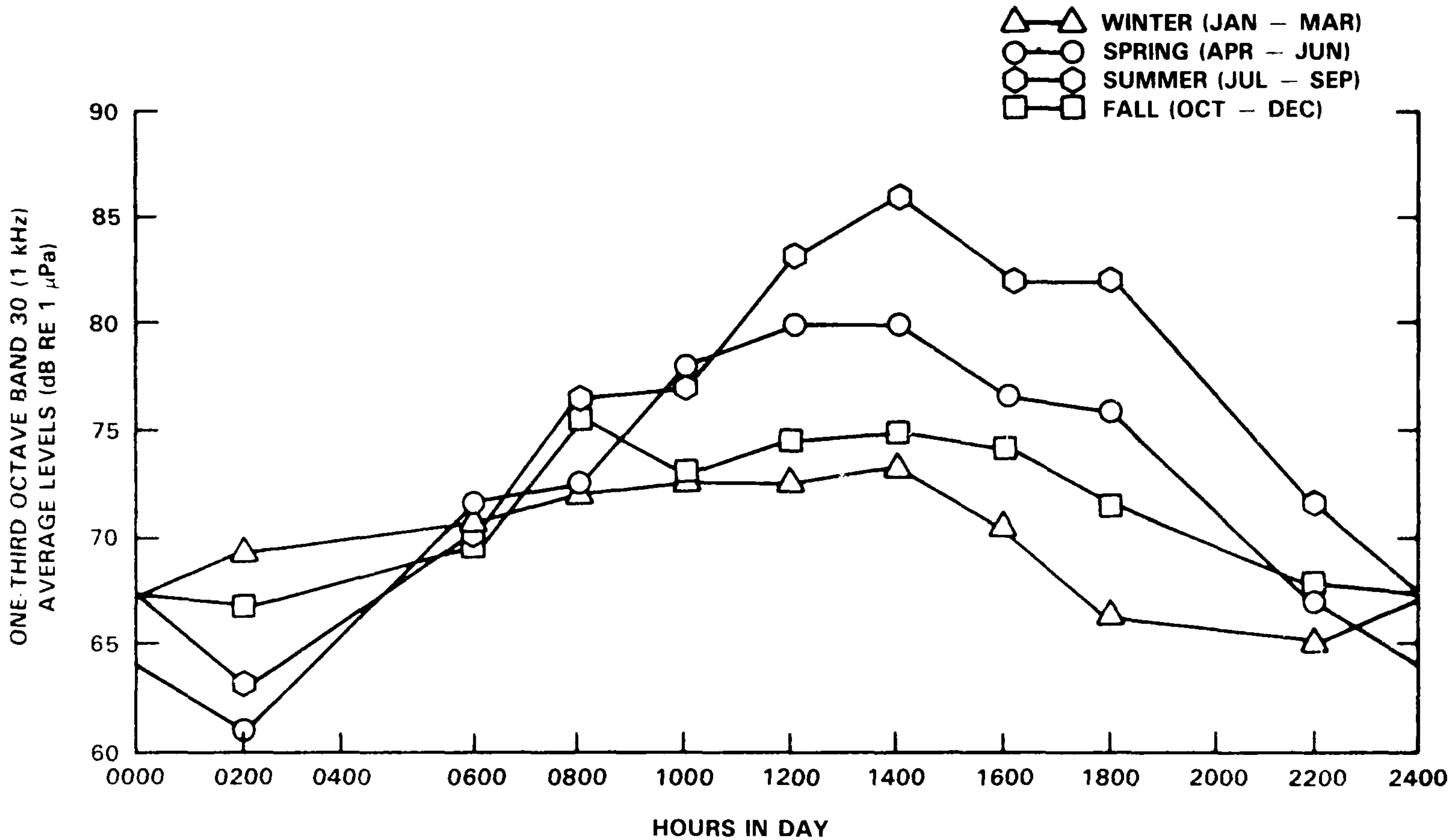

Fig. 10. A comparison of 1986 seasonal daily averages for one-third-octave band 30 (1 kHz).

boat noise (see Fig. 9). It is also interesting to note that a smaller cycle (5- to 7-dB midday increase) may be seen in the average winter level cycle. This characteristic is not clearly understood but may be a consequence of minor midday winter boat traffic or an unknown natural periodicity in the daily noise levels generated by weather-related phenomena.

Weekly Trends

Recreational boating from both fishing and pleasure crafts is more active on the lake during the weekends. This trend is more prominent during the summer months than in the winter, although sporadic boat traffic is present on the lake even during the colder months. Average midweek levels should be uniformly distributed from Monday through Friday, with an increase in levels for Saturday and Sunday. A summary of the 1986 weekly averages is presented in Table 3 and a selective comparison is plotted in Fig. 11 which shows that the composite average for the weekly levels is several dB higher for Friday and Saturday than for Sunday through Thursday. Averaging the fall and winter days of the week gives a better representation of the average weekly levels in the absence of boat noise. With the exception of Friday levels, the other six days of the week are about the same level - 70-71 dB. It is unexplained why fall and winter Friday levels are several dB higher than other days. The spring and summer average weekly levels follow a more predictable trend. Average weekend levels are up to 5 dB higher than midweek levels due to the increased boat noise.

Table 3. A weekly summary of the average 1986 1-kHz, one-third-octave band Lake Pend Oreille ambient noise statistics.

COMPOSITE WEEK – 1 THRU 52 (4-hour INTERVAL AVERAGES)

	SUN	MON	TUE	WED	THU	FRI	SAT
EVENTS	188	176	186	198	190	192	198
AVERAGE	72.1	71.9	71.2	70.8	71.1	73.9	73.2
STD DEV	13.1	11.4	10.7	11.0	11.4	11.3	11.9

WINTER WEEKS (JAN – MAR) (4-hour INTERVAL AVERAGES)

	SUN	MON	TUE	WED	THU	FRI	SAT
EVENTS	44	38	47	56	49	47	45
AVERAGE	72.2	72.8	66.4	66.5	67.2	75.8	69.4
STD DEV	12.8	12.5	12.2	11.0	11.4	14.2	11.8

SPRING WEEKS (APR – JUN) (4-hour INTERVAL AVERAGES)

	SUN	MON	TUE	WED	THU	FRI	SAT
EVENTS	30	25	31	33	33	32	33
AVERAGE	73.4	70.4	72.1	71.5	71.3	71.4	77.3
STD DEV	13.7	12.3	10.2	11.0	10.0	11.3	12.3

SUMMER WEEKS (JUL – SEP) (4 hour INTERVAL AVERAGES)

	SUN	MON	TUE	WED	THU	FRI	SAT
EVENTS	62	60	55	46	48	60	62
AVERAGE	73.7	73.0	73.5	73.8	72.0	76.5	77.9
STD DEV	13.1	10.9	10.0	10.7	12.9	9.6	11.7

AUTUMN WEEKS (OCT – DEC) (4-hour INTERVAL AVERAGES)

	SUN	MON	TUE	WED	THU	FRI	SAT
EVENTS	52	53	53	63	60	53	58
AVERAGE	69.4	70.6	72.4	72.1	73.4	70.6	69.0
STD DEV	12.6	10.5	11.5	9.9	10.1	8.9	9.2

COMPOSITE WEEK – 1 THRU 52

	0200	0600	0800	1000	1200	1400	1600	1800	2200
SUN	63.7	68.8	75.4	75.2	79.0	81.5	79.6	74.2	66.8
MON	63.6	70.7	74.1	73.9	76.9	77.5	72.3	72.3	70.8
TUE	67.8	71.7	72.5	73.5	76.6	75.9	74.9	72.1	65.7
WED	65.8	69.6	73.6	74.2	76.5	76.5	75.3	70.0	68.4
THU	63.9	70.0	73.4	73.5	76.4	77.6	73.9	72.9	68.0
FRI	66.2	71.3	75.9	77.6	78.4	79.7	77.0	75.7	71.2
SAT	66.4	71.4	76.9	75.7	78.8	79.5	79.7	77.6	67.7
EVENTS	205	214	222	238	237	227	228	220	224
AVG	65.5	70.5	74.5	74.8	77.5	78.3	76.1	73.6	68.4
STD DEV	11.3	10.3	10.3	10.7	10.3	10.4	11.0	12.4	10.4

NOTE: 1 kHz LEVELS (dB RE 1 μPa)

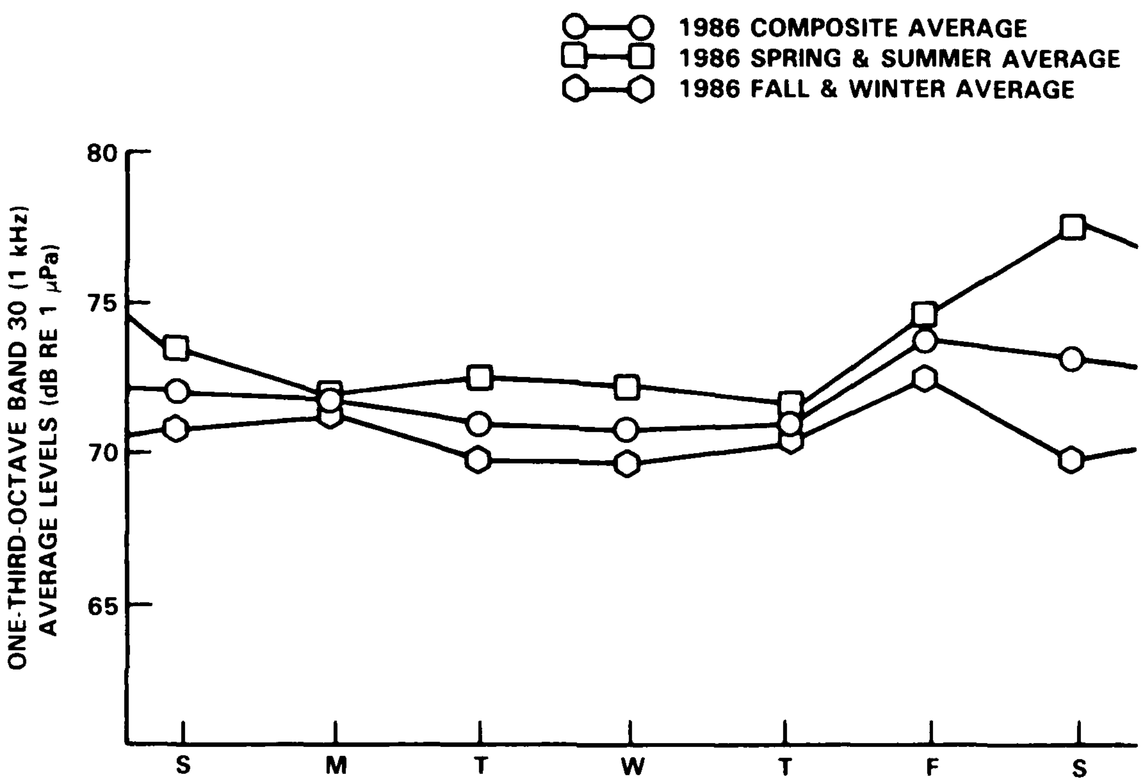

Fig. 11. (U) A comparison of the 1986 composite to seasonal trends in one-third-octave band 30 (1 kHz) average ambient noise levels (average of readings at 0200, 0600, 1000, 1400, 1800, and 2200 hours) for days of the week.

Monthly Trends

Averaging levels for the six 4-hour interval daily readings for all days of each month produces an overall monthly average ambient. These monthly averages are summarized in Table 1 and plotted in Fig. 12. If weather-generated lake noise is distributed evenly throughout the year, and if recreational boat noise is concentrated in the summer months, then summer levels should be markedly higher than winter levels. This summer-to-winter difference provides a measure of the contribution of boat noise to the overall annual ambient noise cycle. To some degree, Fig. 12 shows this to be true. March, April, October, and December monthly averages are significantly lower than those of May through September by some 7-8 dB. November levels are elevated because it was unusually stormy on Lake Pend Oreille during that month (see Fig. 13 and later discussion). Separating the average nighttime and daytime levels further accentuates these differences as seen in Fig. 14. Summer midday levels are about 10 dB higher than the winter midday levels. Nighttime monthly levels are nominally the same from March through December - within 5 dB. January and February levels are somewhat elevated due possibly to unusually stormy nights for these months or to some natural trend in the winter weather patterns common to the Lake Pend Oreille area. The effects of summer boating are better seen in Fig. 15. A comparison of the nighttime to daytime noise spreads (plus or minus one standard deviation from the mean for mean monthly ambient levels) shows similar values for ambient levels during winter months (no boat influence) and approximately 20 dB difference in nighttime and daytime levels during the summer months. This comparison provides a measure of the extremes in quiet and noisy periods in the annual cycle of Lake Pend Oreille ambient noise.

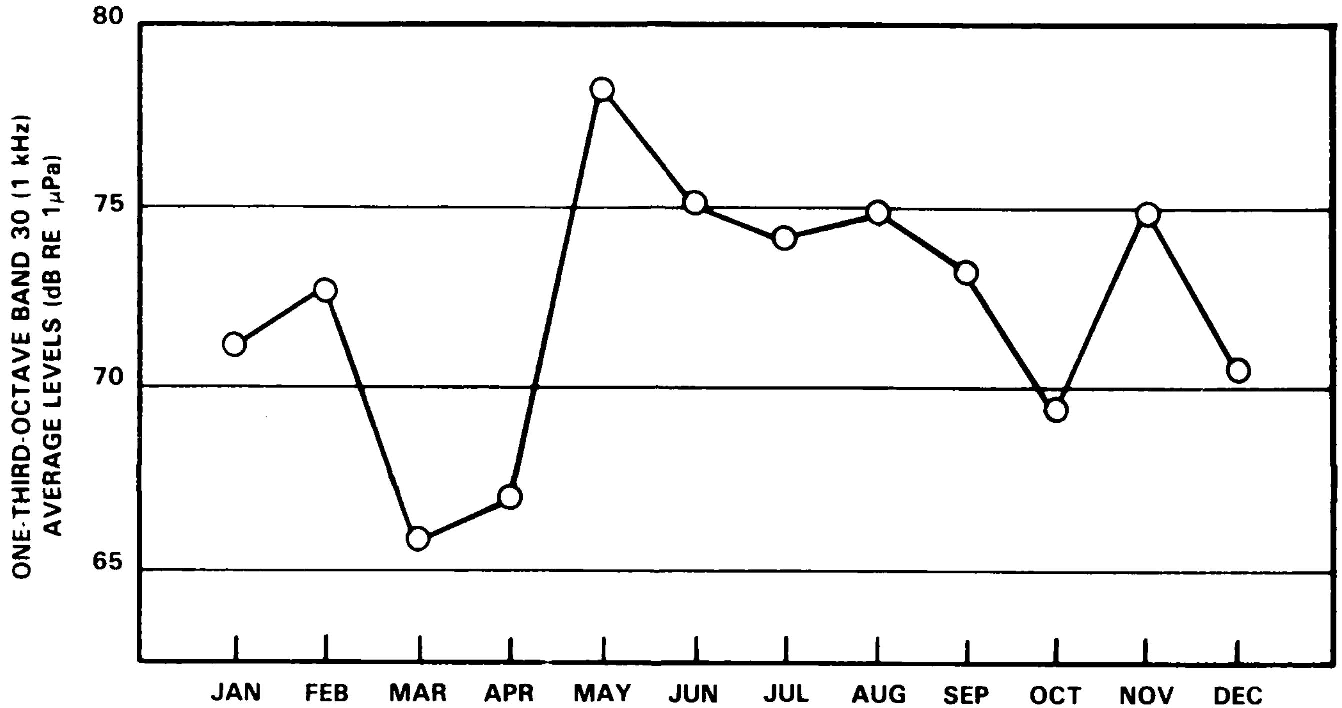

Fig. 12. (U) Average one-third-octave band 30 (1 kHz) ambient noise levels (average of readings at 0200, 0600, 1000, 1400, 1800, and 2200) for 1986.

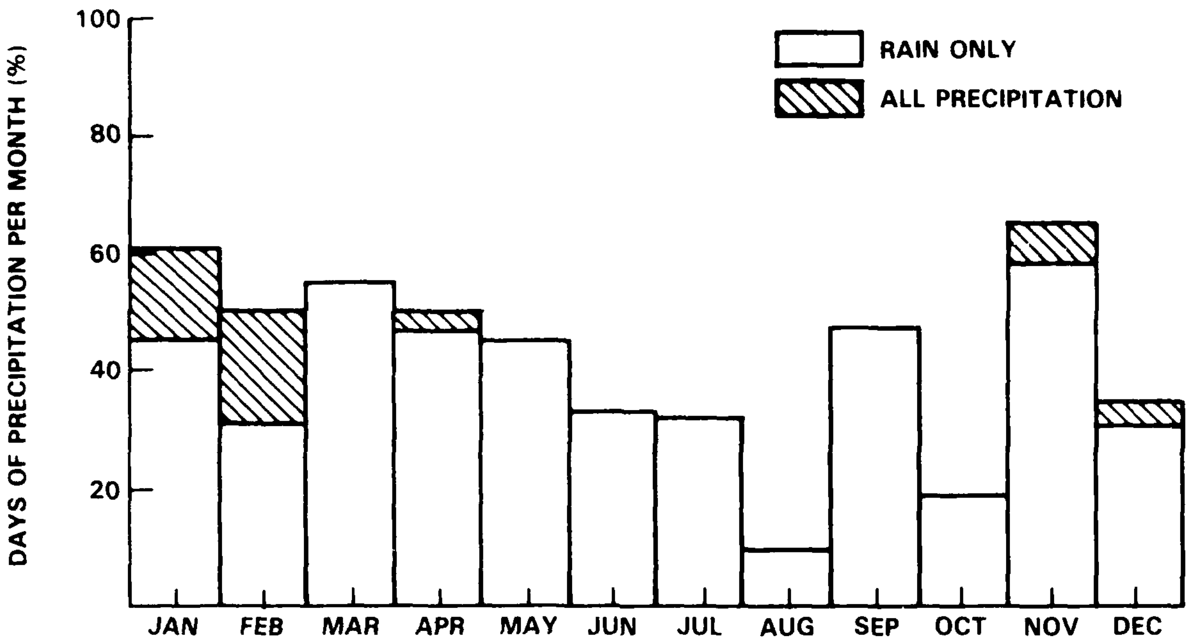

Fig. 13. A histogram of the 1986 monthly distribution of precipitation on Lake Pend Oreille measured at Bayview.

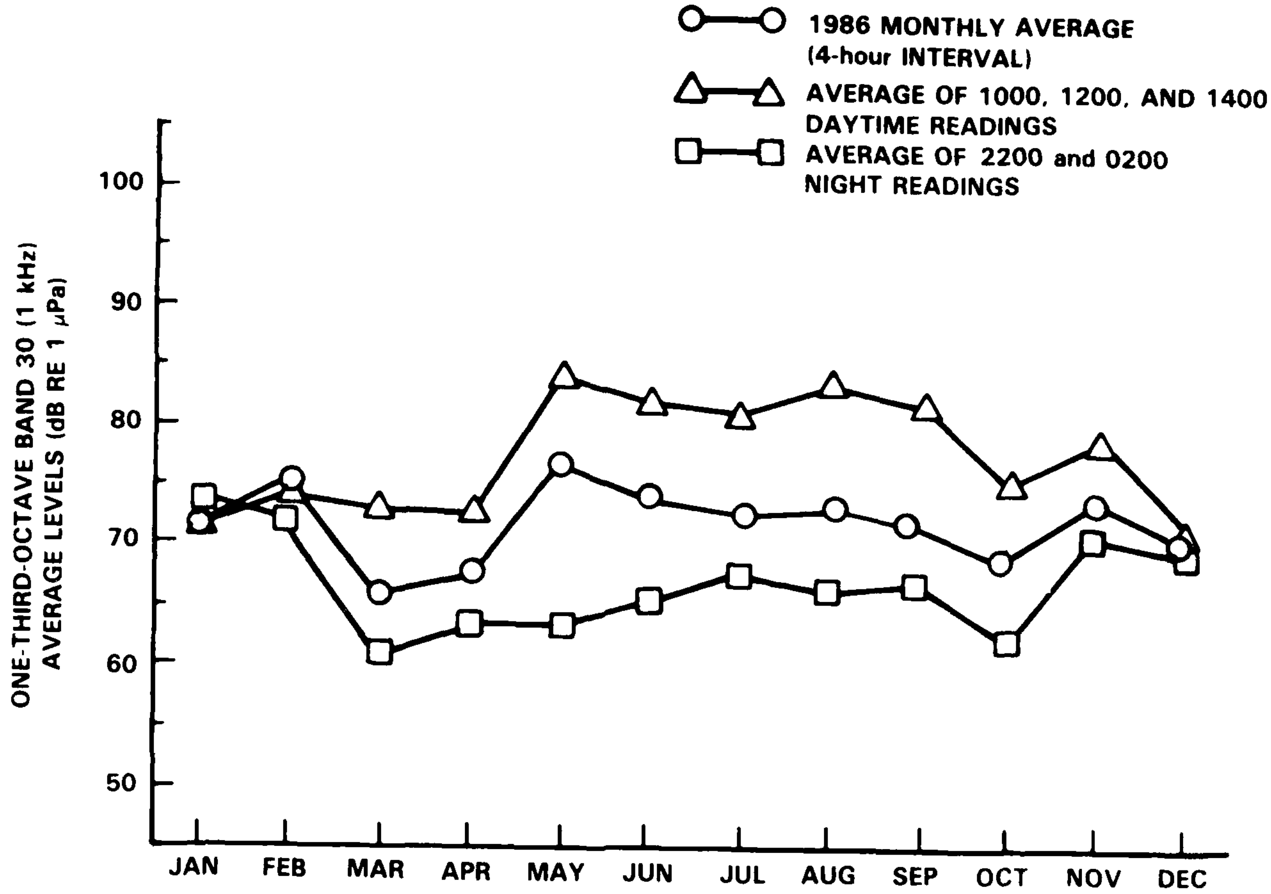

Fig. 14. A comparison of the 1986 composite, daytime and nighttime monthly averages for one-third-octave band 30 (1 kHz).

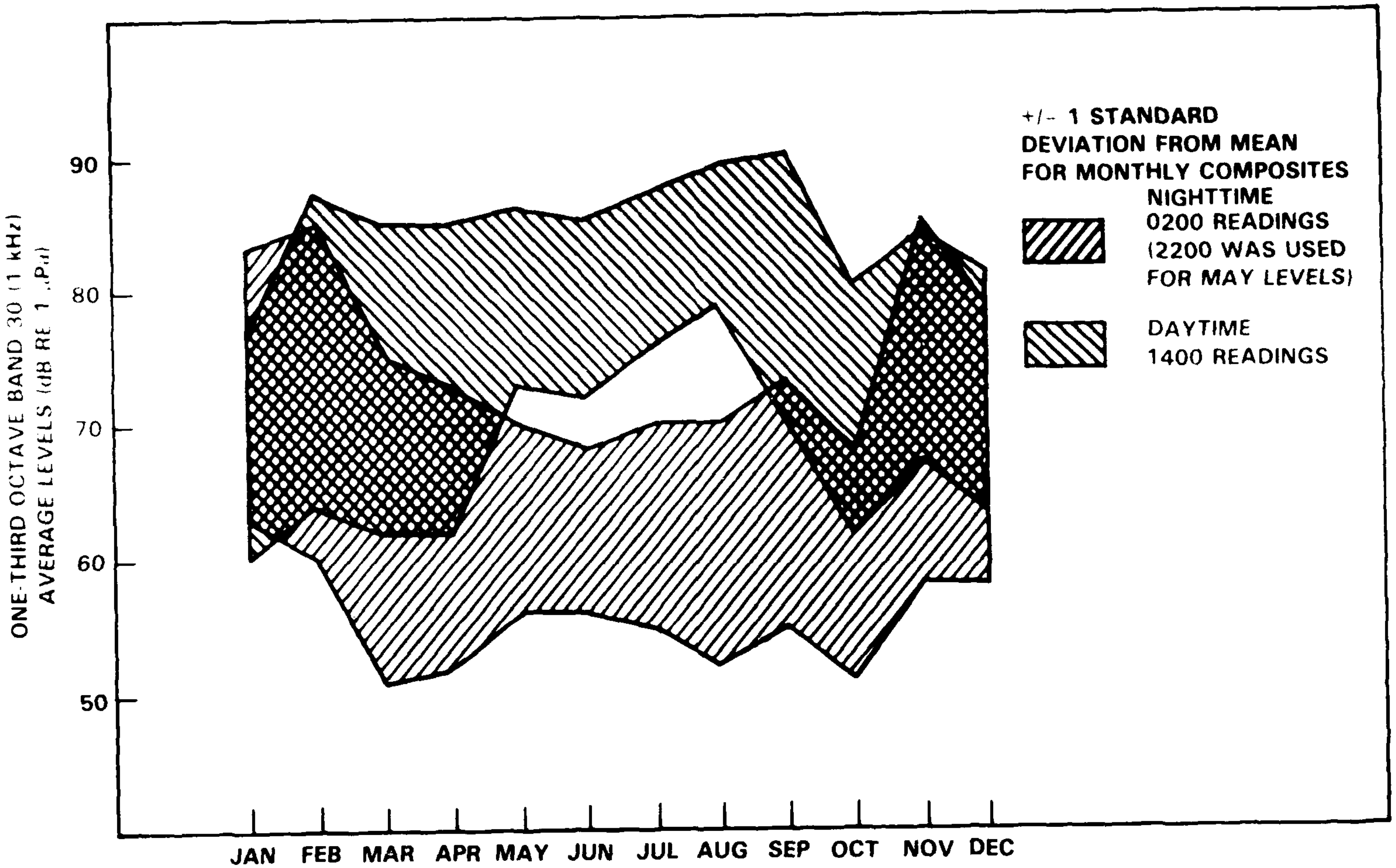

Fig. 15. A comparison of nocturnal to diurnal ambient noise spreads for one-third-octave band 30 (1 kHz) for 1986 monthly averages.

Figure 13 presents a histogram of the percentage of days of each 1986 month in which precipitation was recorded. These daily readings were based on a single citing obtained during each day and include everything from trace to all-day continuous rain. They were recorded at Bayview (approximately six miles south of the deep moor) and not at the ambient measurement site, so they should be used to obtain general Lake Pend Oreille area trends rather than specific monthly rain rate at the ambient recording station. Late summer months are dryer in the Pacific Northwest than are other months of the year. If ambient noise levels were controlled by rain-related phenomena, then one would expect the late summer levels to be reduced. As previously discussed, this is not the case due to the dominating effect of summer boat noise which supports the argument that the average summer levels are not controlled by rain-generated noise. Other months may have a higher dependency on weather although this is not completely certain. January, February, and November are wet months with high ambient levels while March and April are equally wet months but have lower ambients. More annual data is needed.

Cumulative Noise Levels

One of the functions of the DTRC and the Acoustic Research Detachment is to schedule the lake experiments. Since many of the experiments depend on a low ambient noise, a knowledge of the probable ambient is helpful in test scheduling. Use of the measured data in this report allows for computing cumulative probabilities. Figure 16 compares the probabilities for four general times of the day: morning, afternoon, evening, and night. It is readily seen that the probability of acquiring a quiet ambient is significantly greater at night than at the other compared times.

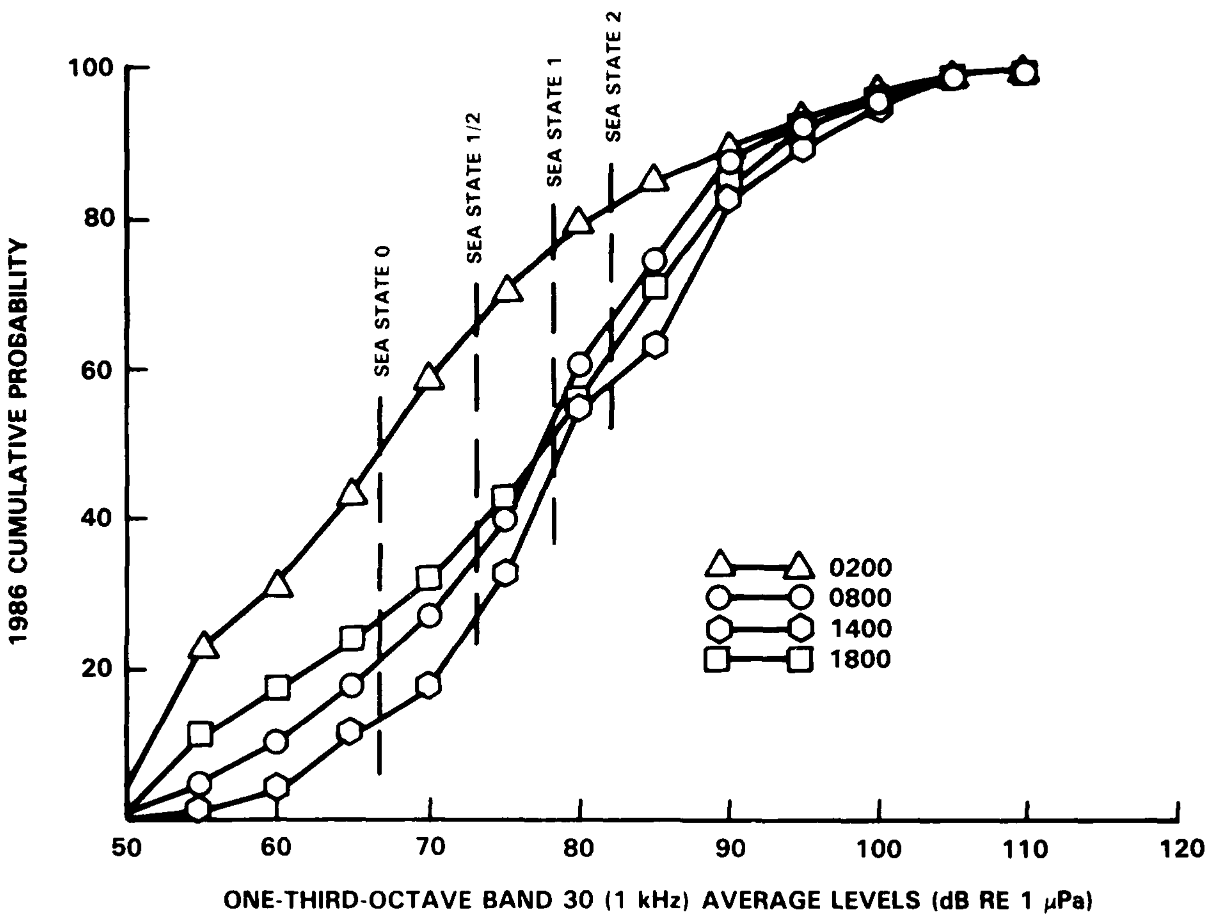

Fig. 16. A cumulative probability comparison of average 1986 one-third-octave band 30 (1 kHz) ambient noise levels for four selected daily times.

CONCLUSIONS

1. Lake Pend Oreille ambient noise spectra between 400 and 20,000 Hz are shaped similarly to the Knudsen sea state curves. These broadly distributed spectra allow the changes in magnitude from one ambient level to another to be well approximated by monitoring the changes in level of any single one-third-octave band within the 400- to 20,000-Hz frequency range.

2. Two distinct cycles were observed in the 1986 ambient noise data: daily and weekly.

   The average hourly noise levels cycle from a daily low of 65 dB re 1 μPa at 0200 to a high of 78 dB at 1400. Recreational boating accounts for 5-8 dB of the midday increases. A seasonal breakdown of the daily cycle shows the differences to be greatest in summer - up to 20-dB day-night difference - and least in winter - 7-dB day-night difference.

   The average weekly cycle ranges from a midweek (Monday to Thursday) low of 72 dB to a weekend high of 75 dB. Recreational boating accounts for the elevated weekend levels.

3. A yearly cycle is evident with higher levels in the summer and lower levels in the winter, although more data are needed to better define the weather and boat contributions to this cycle.

4. Quietest average yearly levels of about 55-60 dB were found for the midweek nighttimes during winter and spring. Highest average yearly levels of 85-90 dB were found for weekend middays during summer.

RECOMMENDATIONS

1. Continually acquire and analyze ambient noise data over a period of years to better quantify Lake Pend Oreille trends.

2. Monitor lake surface using video equipment set to trigger simultaneously with audio measurements. Correlate weather phenomena with the noise measurements and determine of the cyclic nature of rain, wind, and waves on Lake Pend Oreille.

3. Make similar comparisons at other active and potentially active acoustic testing ranges.

4. Install ambient measuring system with lower noise floor in Lake Pend Oreille.

ACKNOWLEDGMENTS

This study was made possible by the generous assistance of a number of individuals. John Dane, Beth Smeltzer, and Marsha Ritzheimer of DDL OMNI Engineering were instrumental in providing data reduction for the large number of 1986 ambients. Marsha also kept meticulous logs and provided valuable assistance in plotting and summarizing the data. In addition, Giles Ledford and William Hoover of the DTRC Ship Acoustics Department willingly lent their technical expertise and constructive criticism during all phases of the experiment. The efforts of all these persons are greatly appreciated.

APPENDIX A

AMBIENT MEASUREMENT SYSTEM

DATA ACQUISITION HARDWARE

The hydrophone array and cabling used to acquire all reported ambient data was one of the three arrays originally installed in Lake Pend Oreille to make radiated-noise measurements on the ARD buoyant test vehicles. The array is located within the deep moor test site at the southern end of Lake Pend Oreille approximately one mile off the western shore and at a depth of 500 ft (see Fig. A.1).

The 32-in. linear array used for ambient data acquisition is an Ithaco model number 97046 and consists of 32 transducers divided into three stacks. Stack A is 3.5 in. long and uses 6 transducers, stack B is 10 in. long and uses 18 transducers, and stack C is 20 in. long and uses all 32 transducers. The nominal open circuit crystal sensitivity of each stack is -172 dB re 1V/μPa as determined in January 1983 by the Underwater Sound Reference Division of NRL of Orlando, Florida. The sensitivity of stack A was confirmed in situ at Lake Pend Oreille in October, 1986. The array output displays temperature sensitivity (±1 dB) for temperatures between 1 and 25° Celsius. The outputs of stacks A, B, and C are omnidirectional in both the horizontal and vertical planes below 12.5, 4, and 2 kHz, respectively. Each stack is wired to a separate low-noise preamplifier which provides 15 dB of realizable signal gain. One calibration circuit within the assembly serves the three preamplifiers. The spectral noise floor of the hydrophones used within the array as provided by the manufacturer is given as 25 dB re 1 $\mu Pa^2/Hz$ at 1 kHz (49 dB re 1 μPa at one-third-octave band 30 - 1 kHz). The array is connected to 3340 ft of shielded, 4-conductor FSS-2 cable.

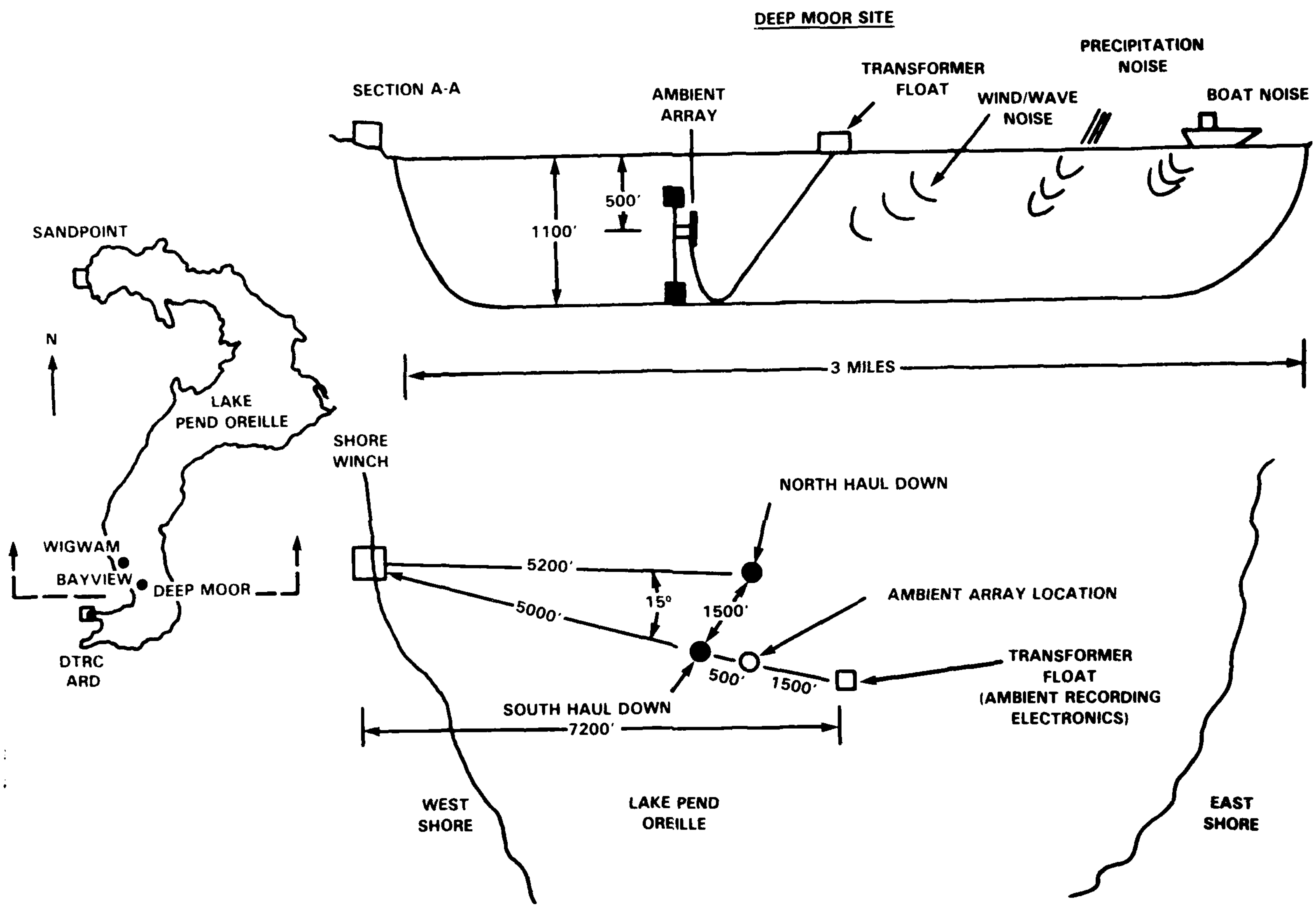

Fig. A.1. Ambient array location.

The line loss of the cable was measured before installation in 1983 and found to be nominally 4 dB for the 3340 ft length. Stack A was used for all reported measurements due in part to its greater omnidirectionality.

The hydrophone was vertically aligned and attached to a bottom anchored subsurface float assembly. The array cable was suspended from the array to the lake bottom, then up to the lake surface, and terminated at a permanently moored transformer float located approximately 1500 ft horizontally from the array. A 13,000-V, 60-Hz, three-phase power line was provided from the local power company to the transformer float via a shore based underwater cable. (The high power was necessary to supply large wattages to the temporary barges that often dock with the transformer float. An adverse consequence of the high power is the generation of 60-Hz noise local about the transformer float and array. This noise affected most of the ambient readings for frequencies below 400 Hz but did not affect the higher frequencies.) The end-of-cable output of stack A was connected to two parallel Ithaco 451 postamplifiers which were set at high-pass, 100-Hz rolloffs and at gains of 45 and 65 dB. The low and high gain amplifier outputs were connected to channels 1 and 2, respectively, of a 14-channel, Ampex FR1300A tape recorder with a 45-dB broadband dynamic range. (A 28-channel Honeywell 5600E tape recorder was substituted for the 14-channel deck from Julian days 141 through 342 of 1986, to allow repair of the Ampex Recorder.) The amplified outputs were recorded as FM, Wide Band I (108-kHz carrier, 20-kHz bandwidth) signals at a tape drive speed of 30 in. per second. A noise floor check of the Ampex recorder/post amplifier combination performed

using a 50-ohm load with the amplifier set at high run gain (65 dB) was found to be (equivalent pressure) about 52 dB re 1 Pa at one-third-octave band 30 - 1 kHz. (The noise floor of the Honeywell was not measured. Readings of 50 & 51 dB were obtained on occasion during 1986. Total system calibration and sensitivity inaccuracies of ±1-2 dB will account for the lower readings.) One inch wide, 4600-ft long wideband Ampex magnetic tapes were used for the ambient recordings. Channel 14 of the tape recorder was connected to a Systron and Donner Model 8154 time code generator/reader complete with DC battery backup and day options. The day was initially set to a Julian calendar and the time to a 24-hour clock calibrated to local time (Pacific Standard). No adjustments in the clock were made for daylight savings time. All data acquisition hardware was continuously powered. An automatic record control timing circuit was wired to the record/drive sequence of the Ampex. The timer was set to trigger the tape deck to make 30 second recordings of the ambient noise at 0200, 0600, 0800, 1000, 1200, 1400, 1600, 1800, and 2200 hours. The readings were concentrated on the daylight hours to give better coverage for times of prime ARD model testing. Fig. A.2 shows a schematic of the ambient data acquisition hardware.

DATA REDUCTION HARDWARE

Each ambient tape, which recorded approximately one week's worth of data, was brought back to the ARD "computer house" for reduction. The tapes were played back on a 28-channel Honeywell 5600E tape recorder set at Wide Band Group I. The playback data channels were 1 and 3 and the time code information, which was read by a Systron and Donner 8154 time code generator/reader, on channel 28. The raw analog ambient data was passed

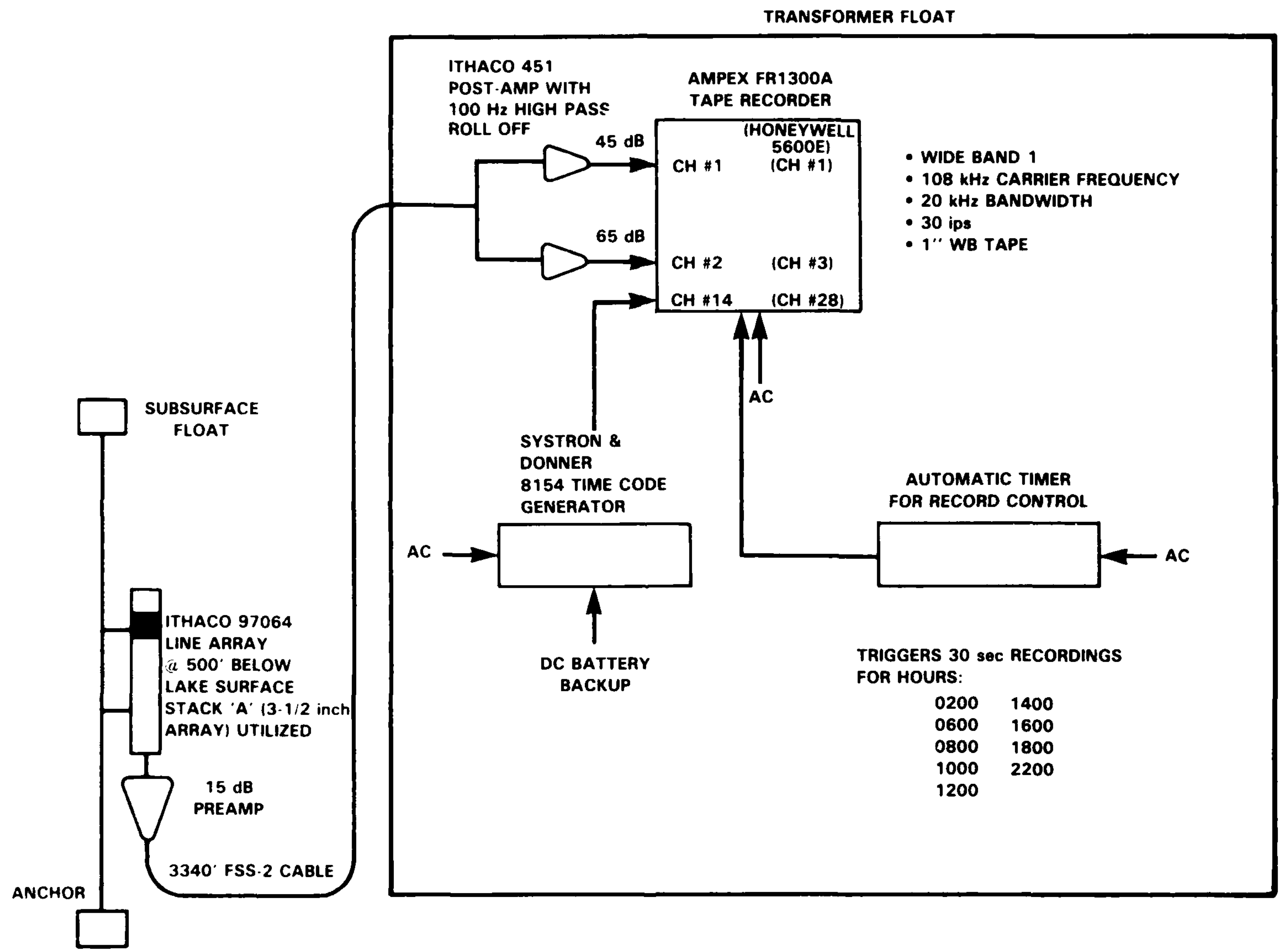

Fig. A.2. Ambient data acquisition hardware schematic.

through a General Radio 1925/1926 multifilter/rms detector suite with all one-third-octave bands of the multifilter set at 0 dB. The rms detector was set for a dynamic range of 0 to -60 dBV for a summed, 0.025- to 20-kHz band level. All reduction hardware was controlled by a Digital Equipment Corporation PDP 11/34 mini-computer. Computer peripherals included a Winchester Disk for mass data storage, a Tektronics 4012 terminal for computer control, and a Tektronics 4631 hard copy unit for data output. An audio amplifier and speaker provided aural monitoring of the data channels.

DATA REDUCTION SOFTWARE

An RT11 version 4 operating system was used by the PDP 11/34 computer for start-up and program/data file maintenance. The General Radio Time Series Language (TSL) was used as the controlling software for all higher level programming and data manipulation. A modified version of the DOLLY VARDEN/KAMLOOPS Data Reduction Program written in TSL and developed by Mr. L. Chandler (DTRC Code 1942) was used to reduce all ambient data to corrected, one-third-octave power spectra. The basic version of the Chandler Program drove the tape recorder, read the time code for time/day event, and instructed the rms detector to take four consecutive, 2-second integrations. These raw spectral cuts were stored as 120 floating point numbers (30 per cut, 0.025- to 20-kHz one-third-octave center bands), and stored on a Winchester Hard Disk as a continuous block file. The program next selectively averaged the four integrations; corrected for post amplifier gain, crystal sensitivity, and electrical system gain (determined by one-third-octave center band calibration); and produced output to hard

copy and disk file as one-third-octave corrected sound pressure levels. The modified version of the Chandler Program read the corrected center band levels of the ambient signatures at 0.4, 1, 4, and 10 kHz and 1 to 20 kHz summed, and stored them as five separate 9-by-365 integer matrices on hard disk (nine time samples per day by 365 days of a nonleap year). The computer operator audibly determined whether the sampled ambient was contaminated by a local, controllable noise source - own work boat for example - and if so, entered a zero manually into the applicable time/day location of the matrices. The matrices provided the data base used for data analysis.

The statistical trends cited in this report were computed from a computer program developed by the author. The ARD Ambient Analysis Program, which was written in TSL to work in unison with the Chandler Program, lists and edits and computes events, averages, and standard deviations of the stored ambient matrices. Standard deviations were computed based on an N - 1 criterion which is customarily used as an unbiased estimator for sampled data (small populations). Matrix values of zero were categorized as nonevents and ignored by the program. Outputs were generated in day, week, month, and composite summaries and reported in either sound pressure level, equivalent Knudsen sea state, or percent formats. Cumulative probabilities were determined. Figure A.3 shows a block diagram of the data reduction hardware and software.

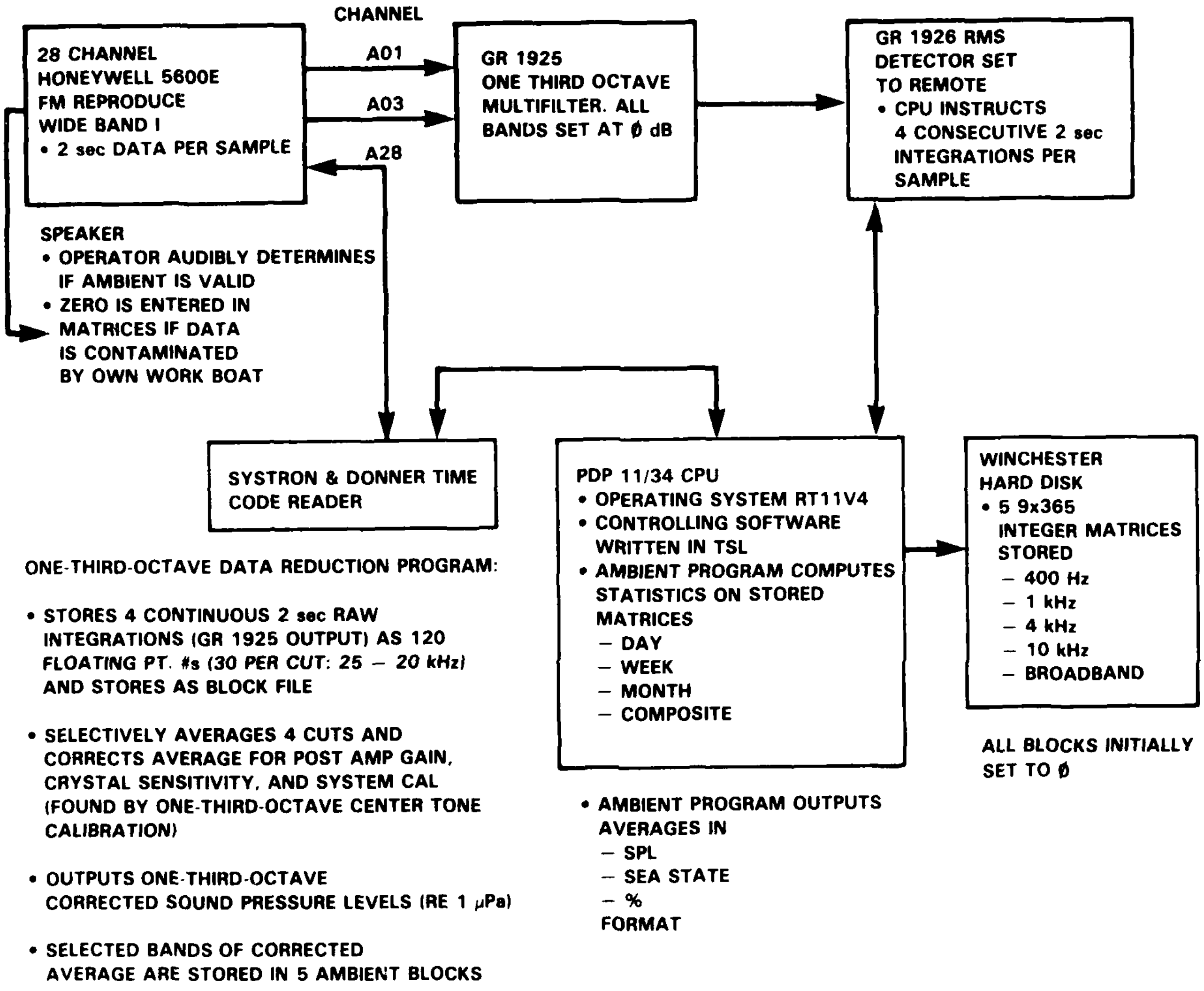

Fig. A.3. Ambient data reduction schematic.

APPENDIX B

1986 ONE-THIRD-OCTAVE RAW AMBIENT NOISE LEVELS
FOR BAND 30 (1 kHz)

Table B.1. 1986 one-third-octave raw ambient noise levels in decibels for band 30 (1 kHz).

(NO AMBIENT DATA WAS TAKEN FOR 0 ENTRIES)

DAY	0200	0600	0800	1000	1200	1400	1600	1800	2200
				JANUARY					
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	55	57	73	0	54	55
9	68	55	55	93	64	85	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	55	88
14	94	64	0	61	0	52	0	54	0
15	69	75	75	73	0	67	0	56	67
16	72	71	75	79	56	62	61	83	84
17	94	96	96	0	0	83	76	60	0
18	68	74	64	64	62	65	67	65	0
19	76	89	88	81	78	78	72	68	0
20	66	0	0	0	0	0	0	0	0
21	66	73	70	82	58	61	54	60	57
22	79	83	80	79	75	75	66	71	0
23	0	0	0	0	0	0	0	85	0
24	88	90	91	95	88	72	82	74	0
25	69	65	71	84	73	71	65	68	0
26	78	79	76	74	69	62	55	55	0
27	65	69	65	75	65	64	53	54	0
28	75	68	65	63	65	62	58	56	0
29	77	78	80	80	78	75	72	69	65
30	73	69	67	70	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
				FEBRUARY					
32	0	0	0	60	85	84	75	60	53
33	59	68	71	66	78	65	81	62	0
34	56	65	57	75	61	101	70	65	0
35	55	54	59	67	61	0	73	53	61
36	65	72	78	79	70	72	67	64	0
37	68	75	73	74	70	65	62	64	0
38	75	81	81	74	65	65	54	70	0
39	67	74	73	78	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0
45	0	0	0	81	84	81	84	83	90
46	95	88	88	88	88	83	81	79	0
47	96	92	91	93	94	88	92	93	0
48	87	87	84	75	85	87	87	81	0
49	55	72	71	76	88	91	89	89	0
50	83	81	75	81	69	68	62	67	80
51	79	68	71	69	76	73	81	53	61
52	87	83	79	87	79	75	58	55	59
53	80	69	56	54	55	50	58	76	74
54	61	70	70	59	65	57	54	55	86
55	85	86	86	92	86	86	85	75	86
56	85	78	85	65	83	85	83	84	85
57	81	65	68	63	62	58	52	54	54
58	65	77	77	77	64	73	63	55	50
59	52	53	54	54	57	0	0	0	0

DAY	0200	0600	0800	1000	1200	1400	1600	1800	2200
				MARCH					
60	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	90	90	87
67	81	56	64	53	77	56	61	83	54
68	67	58	69	77	62	72	65	75	54
69	0	69	69	74	70	60	53	56	55
70	53	54	54	71	51	51	85	54	51
71	50	53	52	54	56	83	59	56	55
72	51	55	50	56	77	87	60	51	62
73	64	57	53	58	85	84	85	55	55
74	54	0	70	70	74	65	68	54	54
75	55	57	70	77	74	71	79	51	52
76	51	59	98	90	89	68	69	83	74
77	71	69	70	69	70	78	67	56	50
78	50	53	50	52	52	79	58	50	58
79	51	72	65	68	64	62	51	50	50
80	50	87	85	93	93	90	94	85	84
81	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0
84	0	0	0	0	79	79	71	59	55
85	55	58	64	84	79	72	90	51	51
86	50	53	74	50	70	64	0	85	73
87	65	55	89	81	99	90	86	89	90
88	84	78	78	65	74	87	77	74	54
89	64	85	89	87	90	93	85	82	73
90	72	69	68	63	0	0	0	0	0
				APRIL					
91	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	51	53	50	67
93	53	55	59	80	59	84	50	59	57
94	52	50	52	0	67	84	50	69	68
95	72	65	63	71	75	82	80	70	70
96	58	57	57	58	94	87	70	55	56
97	51	61	67	59	54	70	77	0	52
98	54	55	77	56	76	70	55	79	79
99	76	69	79	81	75	0	0	53	52
100	74	85	79	76	82	79	72	66	85
101	57	53	79	66	51	68	67	65	68
102	51	88	86	97	90	86	81	81	84
103	85	82	79	66	60	77	0	50	50
104	50	64	80	93	59	56	0	0	0
105	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0
107	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0
109	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0
111	0	0	0	0	0	0	0	0	0
112	0	0	0	0	0	0	0	0	0
113	0	0	0	0	0	0	0	0	0
114	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0
117	0	0	0	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0

Table B.1. (Continued).

DAY	0200	0600	0800	1000	1200	1400	1600	1800	2200
MAY									
121	0	0	0	0	0	0	0	0	0
122	0	0	0	0	0	0	0	0	0
123	0	0	0	0	0	0	0	0	0
124	0	0	0	0	0	0	0	0	0
125	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0
132	0	0	0	0	0	0	0	0	0
133	0	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	0	0	0
135	0	0	0	0	0	0	0	0	0
136	0	0	0	0	0	0	0	0	0
137	0	0	0	0	0	0	0	0	0
138	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0
141	0	79	57	0	83	82	81	89	79
142	0	0	82	0	84	80	81	81	61
143	0	0	68	0	78	79	65	80	57
144	0	0	89	0	89	91	92	88	56
145	0	0	77	0	90	90	0	0	0
146	0	0	79	0	84	85	0	0	0
147	0	0	88	0	88	72	77	0	0
148	0	0	63	0	81	0	0	0	0
149	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0
151	0	0	0	0	0	0	0	0	0
JUNE									
152	0	0	0	0	0	0	0	0	0
153	0	0	0	0	0	0	0	0	0
154	0	0	0	0	87	79	68	74	69
155	59	84	63	79	69	78	81	69	57
156	61	69	75	68	88	74	80	68	77
157	69	73	83	90	77	82	78	87	73
158	64	77	76	87	88	88	88	95	62
159	59	78	79	87	85	94	97	79	58
160	58	80	59	79	82	75	75	81	75
161	67	76	73	77	84	81	75	74	73
162	56	69	70	68	87	81	77	77	70
163	55	69	67	76	79	82	77	80	72
164	54	76	0	88	84	84	82	84	72
165	58	79	82	82	82	82	88	85	86
166	82	68	78	79	81	86	88	92	60
167	68	62	70	79	74	78	68	76	75
168	54	86	63	81	85	79	92	87	68
169	68	89	75	85	0	0	0	0	0
170	0	0	0	0	0	0	0	0	0
171	0	0	0	0	0	0	0	0	0
172	0	0	0	0	0	0	0	0	0
173	0	0	0	0	0	0	0	0	0
174	0	0	0	0	0	0	0	0	0
175	0	0	0	0	0	85	81	80	74
176	67	66	0	78	78	75	81	81	77
177	62	74	0	85	91	78	78	76	53
178	52	87	0	75	80	79	91	81	64
179	52	72	0	84	84	91	83	88	66
180	74	87	0	86	84	88	82	80	0
181	0	0	0	0	79	96	83	76	62

DAY	0200	0600	0800	1000	1200	1400	1600	1800	2200
JULY									
182	52	62	69	78	103	76	78	84	57
183	61	66	69	79	81	78	78	79	59
184	66	58	75	82	85	84	82	94	72
185	77	78	76	74	90	88	80	91	79
186	68	90	82	89	84	87	85	86	79
187	51	58	74	78	90	88	88	92	76
188	52	67	72	81	78	82	86	83	66
189	50	75	69	66	83	87	80	77	0
190	0	0	0	0	0	0	84	0	83
191	57	72	70	83	76	0	80	0	70
192	75	80	77	79	85	84	77	0	80
193	75	77	78	77	84	0	83	0	84
194	61	73	83	84	90	0	91	0	79
195	54	68	71	55	91	0	80	0	85
196	72	77	79	79	82	0	73	0	65
197	66	72	67	78	94	0	86	0	76
198	80	95	86	85	84	0	80	0	60
199	62	71	89	75	70	89	0	86	61
200	61	70	76	62	0	95	0	88	72
201	54	65	73	52	81	99	0	94	72
202	53	71	78	73	77	89	0	74	72
203	54	66	70	54	87	75	0	83	74
204	68	72	77	83	80	82	0	71	63
205	58	61	79	57	73	88	0	72	71
206	57	68	73	70	82	76	80	81	71
207	70	69	92	65	88	86	0	86	68
208	63	75	0	79	78	92	0	86	76
209	73	94	69	66	86	79	76	81	86
210	80	88	81	82	81	86	85	76	75
211	72	65	67	74	79	82	79	82	76
212	58	61	72	71	79	86	71	66	71
AUGUST									
213	52	69	0	79	0	86	83	77	72
214	50	66	0	80	81	85	88	87	82
215	53	57	86	85	88	90	88	93	58
216	68	68	87	78	84	85	78	86	73
217	83	62	67	73	81	88	70	79	59
218	56	74	83	78	79	89	87	89	73
219	52	60	71	81	88	81	89	80	72
220	53	67	71	77	84	82	85	90	73
221	50	78	82	87	87	94	90	97	72
222	53	63	76	90	84	94	89	88	63
223	61	84	68	64	84	86	78	79	75
224	67	66	83	85	80	94	80	75	70
225	86	60	84	0	0	82	95	90	87
226	56	57	0	88	88	90	90	82	83
227	85	85	0	86	98	90	88	79	67
228	55	66	0	79	85	93	92	85	70
229	64	59	0	76	96	93	93	85	78
230	55	61	0	87	80	90	78	100	66
231	56	68	0	94	78	78	91	77	73
232	68	[illegible]	0	0	0	0	0	89	70
233	53	65	0	58	0	0	88	0	66
234	57	63	73	87	82	84	84	0	71
235	70	73	100	85	86	0	89	0	84
236	70	78	78	84	90	0	87	0	69
237	63	74	70	77	90	0	77	0	75
238	68	93	76	78	87	0	79	0	71
239	54	61	[illegible]	56	85	0	89	0	68
240	53	71	52	62	72	97	85	98	73
241	67	78	75	86	78	76	86	97	87
242	76	63	76	80	88	95	90	97	69
243	64	72	77	81	88	89	85	87	[illegible]

Table B.1. (Continued).

DAY	0200	0600	0800	1000	1200	1400	1600	1800	2200
				SEPTEMBER					
244	70	73	82	87	89	91	85	74	64
245	60	67	72	74	79	83	85	67	60
246	59	62	70	86	92	102	88	0	0
247	0	0	0	0	0	0	0	0	0
248	0	0	0	0	0	0	0	0	0
249	0	0	0	0	0	0	0	0	0
250	0	0	0	0	0	0	0	0	0
251	0	0	0	0	0	0	0	0	0
252	0	0	0	0	0	0	0	0	0
253	0	0	0	0	0	0	0	0	0
254	0	0	0	0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0
256	0	0	0	0	0	0	0	0	0
257	0	0	0	0	0	0	0	0	0
258	0	0	0	0	0	0	0	0	0
259	0	0	0	0	0	0	0	0	0
260	0	0	0	0	0	0	0	0	0
261	0	0	0	0	86	0	0	0	0
262	0	0	80	79	81	84	77	75	70
263	66	77	82	100	80	96	81	77	62
264	58	66	87	77	81	89	83	75	68
265	66	61	63	72	83	65	0	0	0
266	0	0	0	0	0	0	0	0	0
267	0	0	0	0	0	0	0	0	0
268	0	0	0	0	0	0	0	0	0
269	0	0	0	86	83	73	74	74	80
270	78	80	81	98	80	78	77	76	67
271	67	59	73	72	79	80	76	68	63
272	72	75	84	68	77	68	57	56	63
273	75	67	70	68	65	83	66	75	70
				OCTOBER					
274	54	61	65	65	68	61	63	55	55
275	52	78	77	76	76	78	73	68	60
276	55	60	64	67	67	70	0	71	71
277	54	60	58	75	69	78	82	78	63
278	53	53	69	68	76	82	83	75	64
279	52	52	56	62	63	71	71	77	52
280	52	52	53	63	67	63	63	0	54
281	0	61	0	54	0	0	0	0	0
282	0	0	0	0	0	0	0	0	0
283	0	0	0	0	0	0	0	0	0
284	0	0	0	0	0	0	0	0	0
285	0	0	0	0	0	0	0	0	0
286	0	0	0	0	0	0	0	0	0
287	0	0	0	0	0	0	0	0	0
288	0	0	0	0	0	86	72	65	56
289	61	66	95	76	72	72	67	94	56
290	61	67	85	59	72	74	74	76	67
291	64	66	75	84	83	90	72	87	56
292	58	71	75	74	72	89	73	61	57
293	60	71	96	76	66	65	68	66	60
294	73	75	76	89	71	69	80	95	53
295	70	69	80	80	83	73	0	67	59
296	75	72	82	78	73	70	64	67	55
297	70	73	0	0	0	0	78	65	56
298	63	67	89	75	83	79	83	83	55
299	56	57	73	95	75	88	86	77	72
300	88	90	86	82	80	80	74	81	75
301	0	73	85	76	67	69	80	0	63
302	0	79	79	82	94	67	59	0	79
303	0	86	86	88	87	83	85	0	82
304	0	72	75	70	84	79	65	0	66

DAY	0200	0600	0800	1000	1200	1400	1600	1800	2200
				NOVEMBER					
305	0	67	83	67	85	72	85	0	72
306	0	0	0	0	0	0	0	0	0
307	0	0	73	64	88	72	62	0	76
308	0	75	68	63	68	75	68	0	67
309	0	70	0	78	79	66	74	0	67
310	0	74	68	59	0	0	0	0	0
311	0	0	0	0	0	0	0	0	0
312	0	0	0	0	0	0	0	0	0
313	0	0	0	0	0	0	0	0	0
314	0	0	0	0	0	0	0	0	0
315	0	0	0	0	0	0	0	0	0
316	0	0	0	0	0	0	87	85	88
317	84	84	0	78	79	75	75	74	70
318	57	63	0	89	71	71	77	62	73
319	79	77	0	79	89	83	88	87	90
320	0	0	86	88	82	81	88	88	84
321	0	0	87	83	80	70	93	75	68
322	0	0	84	80	73	89	79	83	91
323	0	0	98	93	84	88	86	80	76
324	0	0	90	73	91	96	88	87	81
325	0	0	86	86	86	85	83	86	80
326	0	0	99	68	71	75	87	65	63
327	0	0	83	75	93	95	93	91	92
328	0	0	95	88	94	0	78	71	89
329	0	0	77	74	93	0	84	53	54
330	0	0	85	82	77	75	72	63	55
331	0	0	84	65	82	81	68	58	53
332	0	0	80	78	74	72	81	64	59
333	0	0	78	72	70	79	95	65	68
334	0	0	66	52	65	72	80	66	68
				DECEMBER					
335	0	0	66	56	79	71	60	67	61
336	0	0	65	72	59	62	65	70	70
337	0	0	82	78	84	82	85	83	81
338	0	0	71	75	72	69	73	72	73
339	0	0	0	80	0	0	0	0	0
340	0	0	75	69	66	62	66	65	65
341	0	0	71	56	75	71	71	77	79
342	0	0	61	73	64	0	58	67	74
343	72	65	69	77	68	78	68	69	62
344	69	64	69	69	64	79	57	75	71
345	79	79	80	79	75	70	74	77	76
346	77	69	70	73	73	77	65	68	66
347	62	59	73	73	73	72	69	69	59
348	59	70	65	64	57	72	59	61	56
349	57	55	56	56	61	81	58	55	64
350	73	95	67	69	66	77	61	61	69
351	69	72	74	76	0	80	81	79	80
352	81	83	81	81	78	82	84	84	84
353	85	83	85	83	79	77	75	75	76
354	67	69	67	64	67	65	87	58	60
355	65	61	63	59	54	55	56	56	61
356	61	68	74	73	68	84	64	61	70
357	93	90	82	85	85	0	81	78	65
358	60	61	87	60	78	74	79	74	76
359	70	73	63	59	60	58	59	59	58
360	73	59	57	57	64	78	64	57	58
361	57	57	57	62	63	61	58	61	62
362	59	58	61	81	67	63	80	59	59
363	68	78	71	86	66	70	70	82	90
364	92	87	84	81	86	74	79	76	59
365	63	82	83	82	0	90	86	77	78

APPENDIX C

MONTHLY 1986 HISTOGRAMS FOR LAKE PEND OREILLE
ONE-THIRD-OCTAVE AMBIENT NOISE LEVELS
FOR BAND 30 (1 kHz)

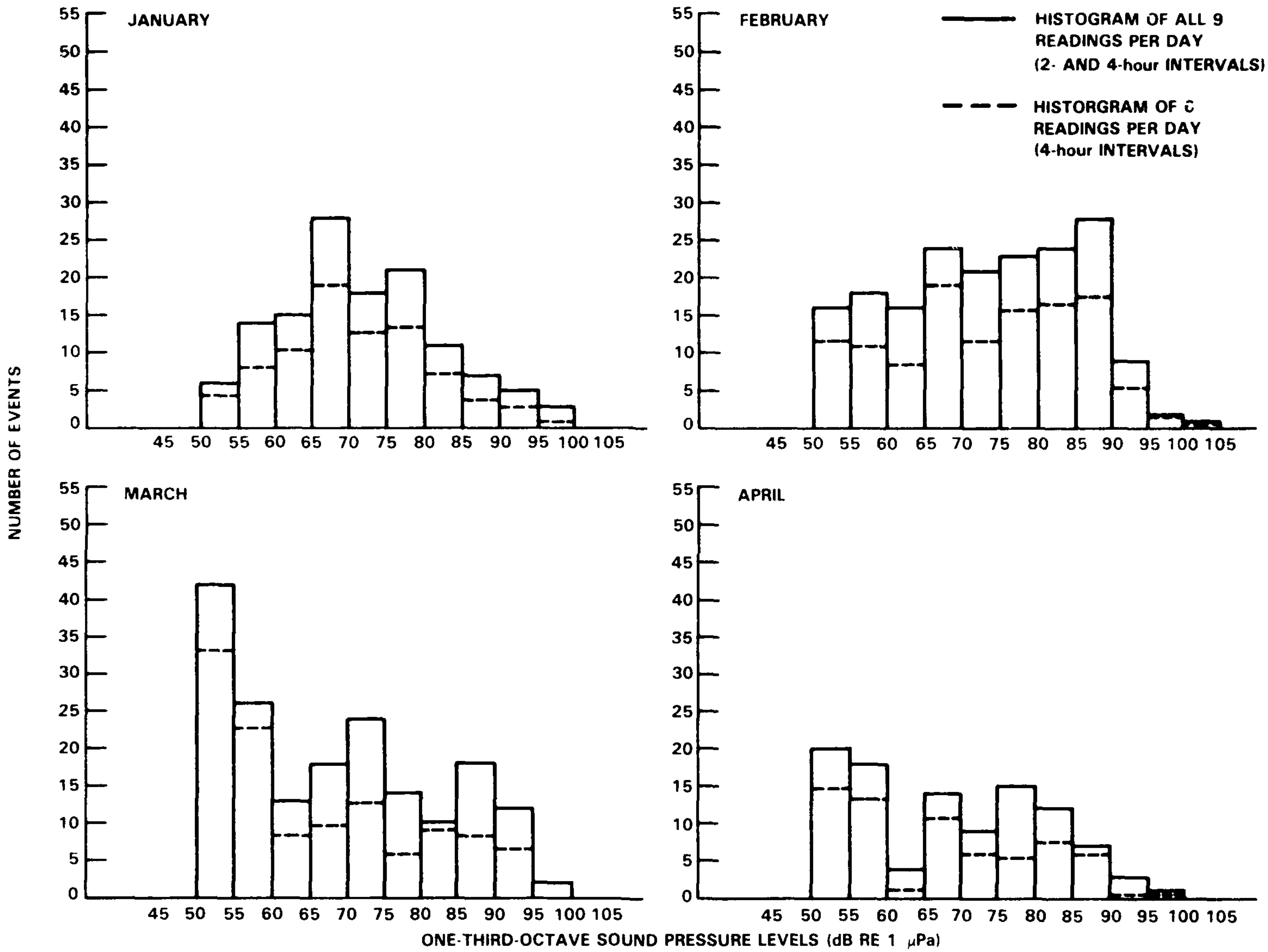

Fig. C.1. Monthly 1986 histograms for Lake Pend Oreille one-third-octave ambient noise levels for band 30 (1 kHz).

Fig. C.1a. January through April.

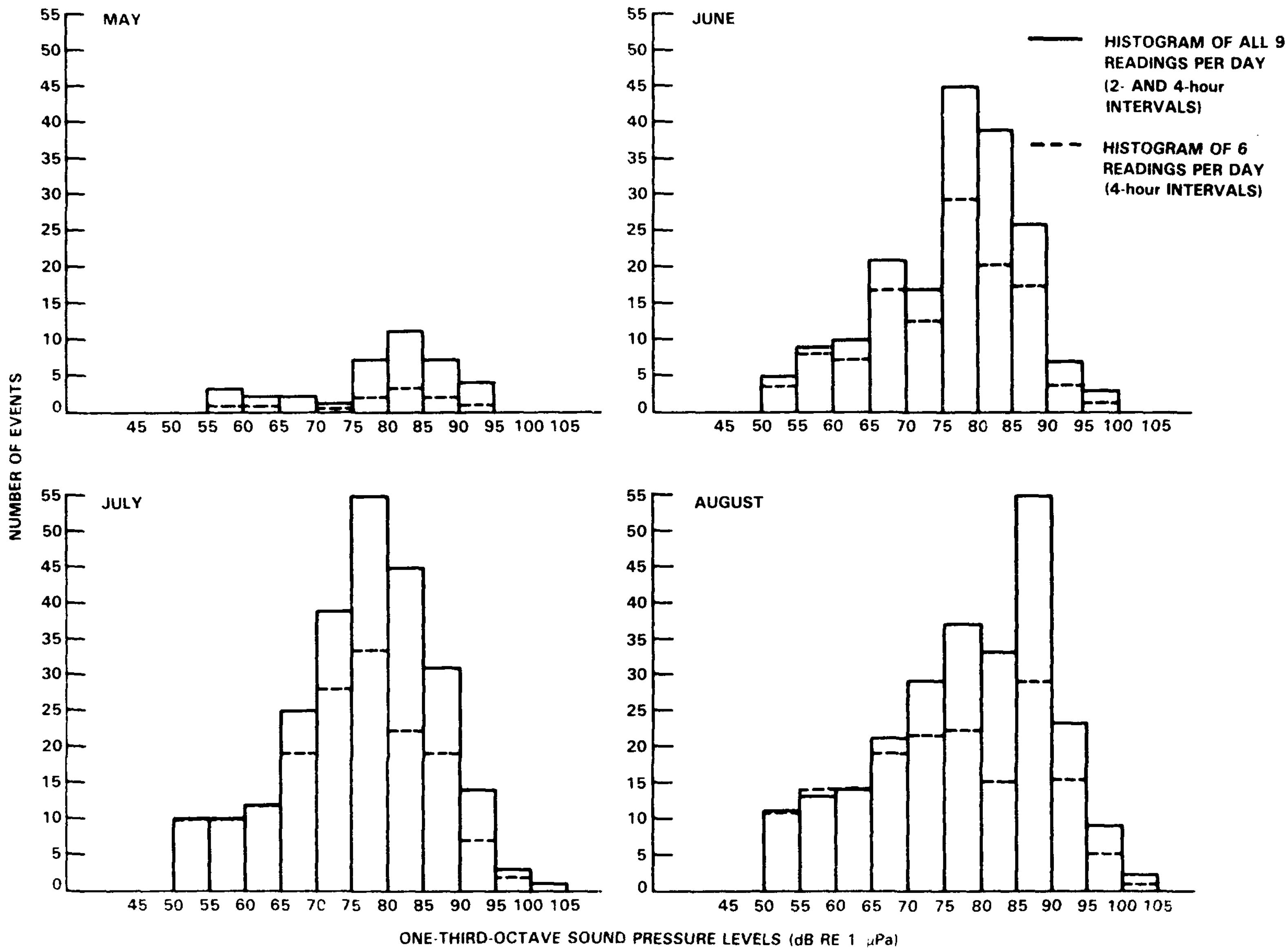

Fig. C.1. (Continued).
Fig. C.1b. May through August.

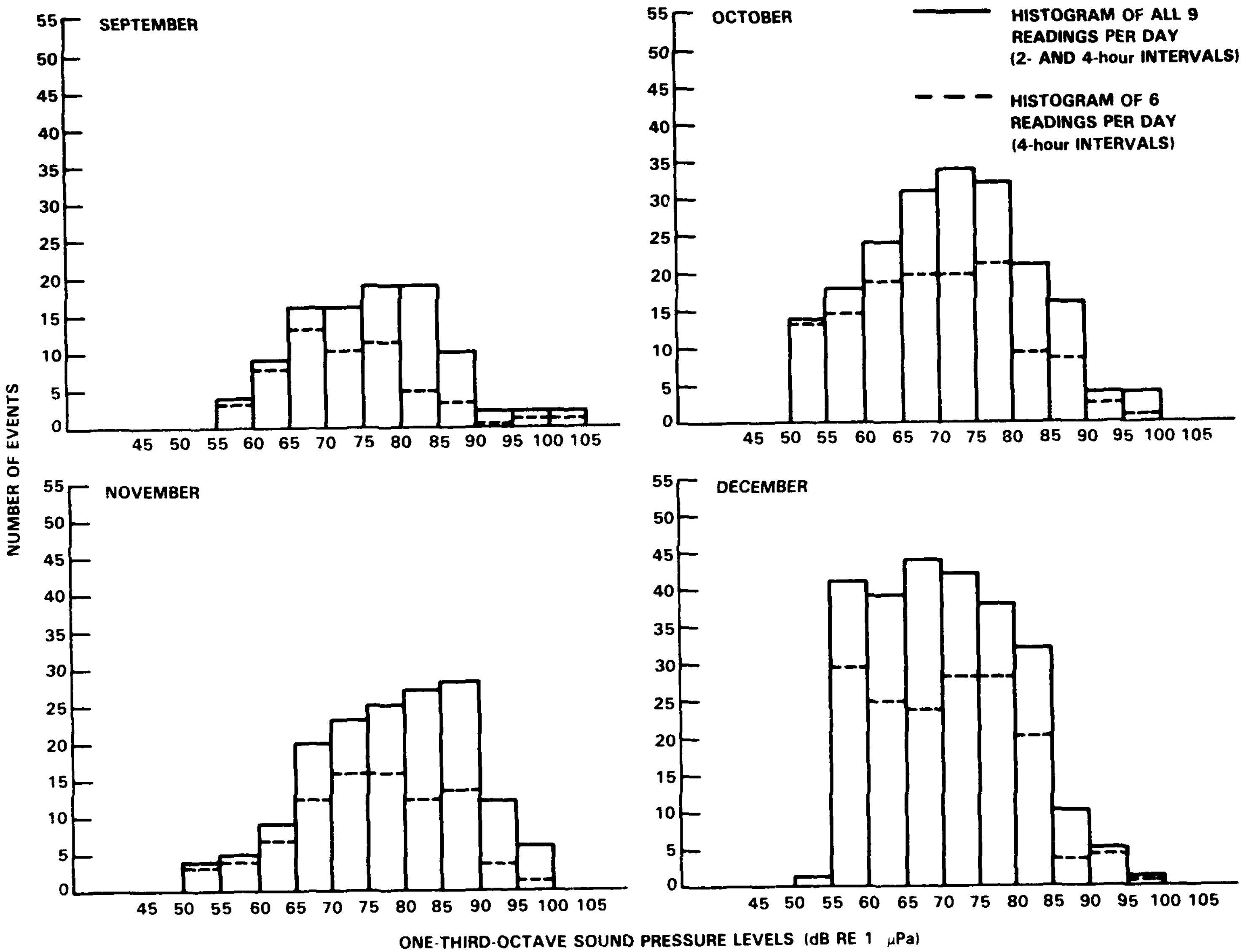

Fig. C.1. (Continued).

Fig. C.1c. September through December.

APPENDIX D

COMPOSITE SUMMARIES FOR 400-, 4000-, AND 10,000-HZ

AMBIENT NOISE LEVEL STATISTICS

Table D.1. A composite summary of the average 1986 400-Hz, one-third-octave band Lake Pend Oreille ambient noise statistics.

	HOURS								
	0200	0600	0800	1000	1200	1400	1600	1800	2200
JAN	74.4	73.6	73.6	76.5	70.0	70.8	68.3	68.4	71.6
FEB	74.0	73.5	73.2	72.8	73.7	75.3	73.8	71.0	71.9
MAR	64.2	65.4	69.2	71.2	75.7	73.8	73.5	68.5	65.2
APR	63.4	65.9	70.4	74.0	71.6	73.8	67.9	64.2	65.6
MAY	0.0	85.0	76.7	0.0	84.6	82.0	80.0	85.0	67.2
JUN	67.6	76.6	75.6	82.0	83.2	84.0	83.0	81.4	69.8
JUL	65.3	73.4	76.0	76.3	83.4	84.7	82.5	82.4	72.3
AUG	64.2	70.3	77.5	79.3	86.0	88.2	85.7	87.4	70.7
SEP	69.8	71.7	77.0	82.5	82.5	82.6	76.9	74.4	67.9
OCT	65.6	69.2	76.3	74.9	76.0	77.1	74.5	76.3	66.7
NOV	75.0	72.1	82.6	75.6	80.4	79.2	80.5	75.1	73.4
DEC	74.1	74.8	73.4	72.9	73.2	74.0	72.9	72.2	72.5

	DAY 1 THRU 365								
	0200	0600	0800	1000	1200	1400	1600	1800	2200
EVENTS	205	214	222	238	237	227	228	220	224
AVERAGE	68.2	71.7	75.1	75.9	78.6	78.9	77.4	75.6	70.0
STD DEV	7.9	8.2	8.4	9.0	8.6	8.9	9.1	9.7	7.3

WEEK 1 THRU 52 (4-hour INTERVAL AVERAGES)

	SUN	MON	TUE	WED	THU	FRI	SAT
EVENTS	188	176	186	198	190	192	198
AVERAGE	74.2	73.6	72.8	72.1	72.4	74.7	74.7
STD DEV	10.7	9.0	7.8	8.6	8.7	9.4	9.9

MONTH 1 THRU 12 (4-hour INTERVAL AVERAGES)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
EVENTS	88	118	120	70	16	125	165	170	64	132	95	165
AVERAGE	72.7	73.1	68.2	67.8	80.5	77.1	75.0	75.7	75.3	71.8	74.9	73.5
STD DEV	8.2	9.1	10.0	9.9	10.0	8.3	9.2	10.8	9.6	8.7	7.6	5.4

NOTE: AVERAGE ONE-THIRD-OCTAVE BAND 26 (400 Hz) LEVELS (dB RE 1 μPa).

Table D.2. A composite summary of the average 1986 4000-Hz, one-third-octave band Lake Pend Oreille ambient noise statistics.

HOURS

	0200	0600	0800	1000	1200	1400	1600	1800	2200
JAN	73.5	73.8	73.1	74.0	67.8	69.2	63.1	62.2	67.0
FEB	71.5	72.7	72.1	71.3	72.2	76.2	70.2	66.6	68.5
MAR	58.4	62.1	68.3	68.7	73.1	74.8	71.8	66.2	59.5
APR	59.9	65.1	71.5	70.5	68.4	73.5	65.4	63.0	65.2
MAY	0.0	78.0	75.1	0.0	82.8	81.7	77.0	84.0	62.0
JUN	60.3	72.5	69.5	77.4	80.2	80.1	77.9	76.2	67.5
JUL	61.6	68.9	72.6	69.5	81.6	83.5	79.1	79.9	71.2
AUG	59.7	65.9	74.2	74.8	82.2	85.5	84.2	85.4	70.1
SEP	63.7	66.5	75.8	77.0	79.3	80.1	74.6	69.2	63.8
OCT	59.5	65.5	75.1	72.7	71.8	72.3	69.3	71.7	59.2
NOV	71.0	68.2	81.1	73.1	78.9	75.2	79.4	71.5	70.7
DEC	67.5	68.4	68.4	68.8	67.1	71.8	66.9	66.5	66.1

DAY 1 THRU 365

	0200	0600	0800	1000	1200	1400	1600	1800	2200
EVENTS	205	214	222	238	237	227	228	220	224
AVERAGE	63.5	68.2	72.7	72.2	75.6	76.9	74.0	71.7	66.5
STD DEV	12.2	11.6	11.6	11.2	11.7	11.0	12.1	13.5	11.3

WEEK 1 THRU 52 (4-hour INTERVAL AVERAGES)

	SUN	MON	TUE	WED	THU	FRI	SAT
EVENTS	188	176	186	198	190	192	198
AVERAGE	69.9	69.8	68.9	68.8	69.2	71.7	71.5
STD DEV	13.9	12.3	11.4	11.6	12.7	12.1	12.7

MONTH 1 THRU 12 (4-hour INTERVAL AVERAGES)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
EVENTS	88	118	120	70	16	125	165	170	64	132	95	165
AVERAGE	70.2	71.5	65.1	77.1	77.1	72.5	73.1	72.6	70.5	67.0	72.1	68.3
STD DEV	12.0	13.1	14.8	10.7	10.7	11.3	11.5	12.4	11.1	12.3	11.9	11.0

NOTE: AVERAGE ONE-THIRD-OCTAVE BAND 36 (4000 Hz) LEVELS (dB RE 1 μPa).

Table D.3 A composite summary of the average 1986 10,000-Hz, one-third-octave band Lake Pend Oreille ambient noise statistics.

	HOURS								
	0200	0600	0800	1000	1200	1400	1600	1800	2200
JAN	72.5	73.1	72.8	74.7	70.3	68.3	66.1	64.6	68.0
FEB	71.4	72.6	71.8	71.4	72.7	73.8	70.2	67.4	69.6
MAR	61.6	64.3	69.4	69.7	72.3	73.5	71.2	68.3	61.9
APR	63.6	66.5	70.3	68.9	70.7	73.4	67.0	64.8	66.9
MAY	0.0	74.0	72.7	0.0	79.1	77.1	75.0	81.2	67.5
JUN	64.1	69.7	67.7	73.2	75.6	75.2	73.5	72.0	67.3
JUL	63.3	66.3	68.8	67.4	77.7	78.8	75.0	75.4	69.2
AUG	63.0	65.2	71.0	71.4	77.3	79.6	79.2	80.7	67.9
SEP	63.2	64.9	73.2	73.5	74.7	77.1	73.0	67.6	62.6
OCT	60.2	64.9	71.9	70.6	72.3	68.6	67.5	69.4	61.2
NOV	72.0	67.1	79.8	74.0	76.9	74.4	78.0	71.7	70.6
DEC	68.5	69.6	69.3	69.6	69.5	71.9	68.8	67.7	67.9

	DAY 1 THRU 365								
	0200	0600	0800	1000	1200	1400	1600	1800	2200
EVENTS	205	214	222	238	237	227	228	219	224
AVERAGE	65.2	67.6	71.3	71.0	74.1	74.2	72.5	70.7	66.8
STD DEV	8.7	9.1	9.7	8.7	9.0	8.7	9.5	10.7	8.3

WEEK 1 THRU 52 (4-hour INTERVAL AVERAGES)

	SUN	MON	TUE	WED	THU	FRI	SAT
EVENTS	188	176	185	198	190	192	198
AVERAGE	69.9	68.9	67.9	68.5	69.1	70.5	70.6
STD DEV	10.4	9.3	8.0	9.2	9.8	9.4	9.6

MONTH 1 THRU 12 (4-hour INTERVAL AVERAGES)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
EVENTS	88	118	120	70	16	125	164	170	64	132	95	165
AVERAGE	70.4	71.6	66.7	67.3	75.6	70.5	69.4	70.3	68.6	66.0	72.1	69.3
STD DEV	9.5	10.0	12.3	11.3	9.5	9.3	9.6	10.3	8.9	10.6	8.8	7.5

NOTE: AVERAGE ONE-THIRD-OCTAVE BAND 40 (10,000 Hz) LEVELS (dB RE 1 μPa).

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